Crash Test Between a Modified G4 (1s) Guardrail System and a 1997 Geo Metro: FOIL Test Number 99F003

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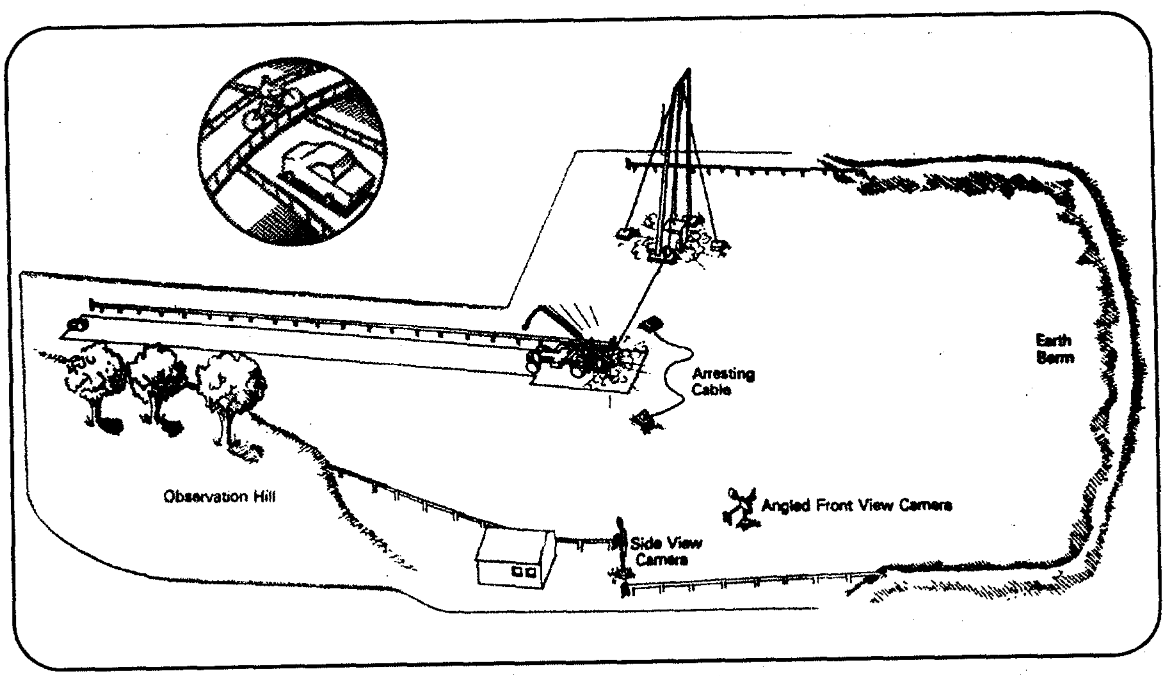

FOIL

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
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FOREWORD

This report documents the results from one crash test between a 1997 Geo Metro two-door hatchback and a modified strong post guardrail barrier (G4(1s)). The Federal Highway Administration (FHWA) has invested many resources in the development of finite element models (FEM) of passenger vehicles, pickup trucks, and roadside safety hardware. Computer simulations using these FEMs of collisions between the vehicles and roadside safety hardware are used to investigate the behavior of and improve the safety performance of roadside safety hardware. An essential step for developing the FEM is to validate the model by comparing data from simulation output with data collected from full-scale vehicle crash tests with roadside safety hardware. The FHWA's Federal Outdoor Impact Laboratory (FOIL) was used to conduct this test to develop and validate an FEM of the Geo Metro. The nominal test speed for the test was 100 km/h and the nominal test weight of the test vehicle was 820 kg.

This report (FHWA-RD-01-048) contains test data, photographs taken with high-speed film, and a summary of the test results.

This report will be of interest to all State departments of transportation; FHWA headquarters; region and division personnel; and highway safety researchers interested in the crashworthiness of roadside safety hardware.

Michael F. Trentacoste

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Office of Safety and Traffic
Operations Research and Development

NOTICE

Technical Report Documentation Page

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16. Abstract

This report contains the test procedures followed and test results from one crash test between 1997 a Geo Metro and a modified G4(1s) w-beam guardrail barrier. The tests were conducted at the Federal Highway Administration's (FHWA) Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The target test speed for the test was 100 km/h and the target test inertial weight was 820 kg. One dummy was placed in the right front seat (struck side of the vehicle). The dummy weighed 75 kg. The test was conducted to provide data for validating a finite element model (FEM) of a Geo Metro and to investigate the potential for wheel snagging problems with small cars. To date, most tests on standard w-beam guardrail barriers have been with large passenger vehicles and pickup trucks to test the strength of these guardrail systems. The results indicate that, although there was minor wheel snagging, the modified G4 (1s) guardrail barrier met the safety performance criteria outlined in National Cooperative Research Program (NCHRP) Report 350, test designation 3-10. The data and high-speed film coverage will aid in the development and validation of the Geo Metro FEM.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
	AREA			
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
	ILLUMINATION			
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
	FORCE and PRESSURE or STRESS			
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

NOTE: Volumes greater than 1000 l shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
	AREA			
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
	VOLUME			
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
	ILLUMINATION			
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
	FORCE and PRESSURE or STRESS			
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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SCOPE

This report documents the procedures followed and the results from one crash test conducted at the Federal Outdoor Impact Laboratory (FOIL) located at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The test involved a 1997 Geo Metro two-door hatchback and a modified G4(1s) guardrail barrier system. The test was conducted to provide data for validating a finite element model (FEM) of a Geo Metro and to investigate the potential for wheel snagging problems with small cars. To date, most tests on standard w-beam guardrail barriers have been with large passenger vehicles and pickup trucks to test the strength of these guardrail systems.

The results indicate that, although there was minor wheel snagging, the barrier smoothly redirected the Geo Metro. In addition, the results indicate that the safety performance values were below the safety performance criteria outlined in the National Cooperative Highway Research Program Report 350 (*NCHRP Report 350*).[1]

TEST MATRIX

One crash test was performed on the G4(1s) guardrail system. The test was conducted in accordance with *NCHRP Report 350* test designation 3-10. Test designation 3-10 outlines parameters for a safety performance test of longitudinal barriers involving an 820C (820-kg) vehicle striking a longitudinal barrier at 100 km/h and at an impact angle of 20°. Table 1 summarizes the nominal test conditions for test 99F003. The target impact location was midway between post numbers 11 and 12 (referenced from the first upstream post of the system), approximately 20 m from the first system post.

Table 1. Summary of nominal test conditions.

Test number	99F003
Test Date	04-08-99
Vehicle	1997 Geo Metro
Vehicle weight	820 kg
Speed	100 km/h
Impact angle	20°
Barrier type	Longitudinal barrier Modified G4(1s)
Impact location	Midway between posts 11 and 12

VEHICLE

The test vehicle used was a 1997 Geo Metro LSi two-door hatchback with an automatic transmission. Prior to the test, the vehicle was drained of all fluids and its curb weight recorded. The vehicle's inertial properties were then measured using the FOIL inertial measurement device (IMD). The vehicle was stripped of certain components (spare tire, rear seat, shifter linkage, etc.) and instrumented with data acquisition equipment, sensors, an automated brake system, a high-speed film camera, and vehicle guidance equipment. The final vehicle test weight was determined and the vehicle's inertial properties were measured a second time as instrumented. The target vehicle inertial weight was 820 kg. No components were removed from the vehicles' engine compartment. The battery remained in a charged state and connected to the power harness. The key was placed in the "start" position to activate air-bag power. A dummy was placed in the front right passenger seat (the contact side of the vehicle). The dummy was not instrumented and was used for ballast and to observe occupant kinematics during the barrier test. The dummy was restrained using the three-point shoulder-lap seat belt system of the Geo Metro. The target test weight including the dummy was 895 kg. Table 2 summarizes the test vehicle's inertial properties and figure 1 lists the vehicle's physical parameters.

Table 2. Inertial properties of 1997 Geo Metro.

Test Number	Weight (kg)	Height (mm)*	Long.cg ** (mm)	Pitch kg•m^2	Roll kg•m^2	Yaw kg•m^2	Bumper Height (mm)	Wheel Base (m)
Curb Weight Configuration								
99F003	823	560	847	1,022	200	1,173	455	2.4
Test Configuration (inertial)								
99F003	832	545	807	948	183	1,120	455	2.4

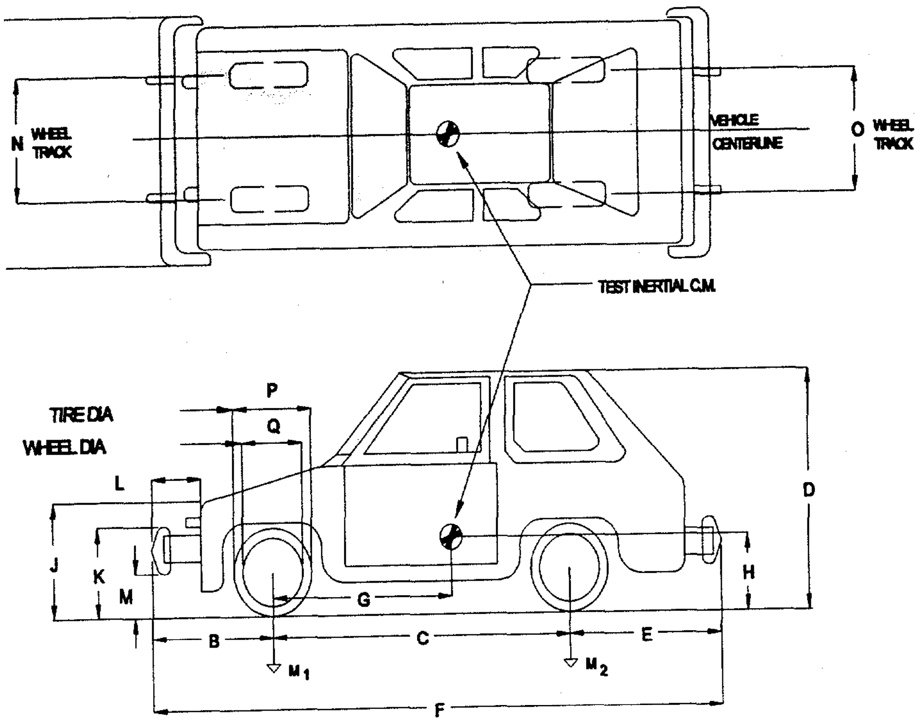
* Height of vehicle center-of-gravity.
** Longitudinal center-of-gravity, distance behind front axle.

DATE: 4-08-99	TEST NO: 99F003	TIRE PRESSURE: 35 psi	MAKE: GEO
MODEL: METRO	YEAR: 1997	ODOMETER: 30,691	GVW: 832
TIRE SIZE:	VIN NUMBER: 2C1MR2297V6742471		TREAD TYPE:

MASS DISTRIBUTION:	LF	RF	LR	RR
CURB:	273	255	146	149
TEST INERTIAL:	288	260	141	143

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:

NONE



ENGINE TYPE: 1.3L 4 CYL.

ENGINE CID:

TRANSMISSION TYPE:

X AUTO

MANUAL

OPTIONAL EQUIPMENT:

AIR CONDITIONING

Radio

DUMMY DATA:

TYPE: Ballast

MASS: 75 kg

SEAT POSITION: right front

GEOMETRY

A 1525	E 591	J 718	N 1385	R
B 830	F 3785	K 502	O 1351	S
C 2363	G 807	L 106	P 577	T
D 1415	H 550	M 410	Q 361	U

MASS	CURB	TEST INERTIAL	GROSS STATIC
M_1	528	548	588
M_2	295	284	319
M_T	823	832	907

1 psi = 6.89 kPa

Figure 1. Vehicle properties for test 99F003.

TEST DEVICE

The device tested at the FOIL was a modified strong post w-beam barrier system (modified G4(1s)). The longitudinal barrier consisted of standard W150 x 12.5 kg/m steel posts spaced 1,905-mm center-to-center. Attached to each steel post was one 150-mm by 205-mm by 355-mm routed wood offset block. The 75-mm wide flange of the steel post was nested in the routed area of the offset block. The wood offset block is considered a modification to the standard G4(1s) barrier system. The wood offset block-to-steel post-to-rail connection was made using one 16-mm by 255-mm long bolt. The connection was made on the upstream side of the steel post. The steel w-beam rail was standard 3,810-mm long 12 gauge w-beam rail. The barrier was installed at a rail height of 685 mm (top of the posts was 25 mm higher). The barrier was installed by a local guardrail contractor. The barrier was laid out using the impact location as a reference and pivoting the whole barrier to the proper impact angle. The impact location was 20 m downstream from the first system post, between posts 11 and 12. The barrier was anchored at each end. The upstream anchor was a LET-2000 end-terminal which was 11.5 m in length. The LET-2000 is a shorter version of an ET-2000 end-terminal (15 m). The downstream end was anchored with a straight blunt-end. The last section of rail was installed with a cable anchor fastened to the last post in a foundation tube. The total length of the barrier installation was 42 m (including all anchorage). Figure 2 illustrates the layout of the barrier installation at the FOIL test facility. Refer to figures 7 and 8 in Appendix A for photographs of the test installation.

INSTRUMENTATION

Speed-trap, accelerometer, and high-speed film data were collected during the barrier test.

Speed trap. A speed trap was used to determine the vehicle's speed just prior to contact with the strong-post guardrail system. The center of the speed trap was placed approximately 8 m before the guardrail. The speed trap consisted of a set of five contact switches fastened to the runway at 0.3-m intervals. As the vehicle passed over the switches, electronic pulses were recorded on analog tape.

Transducer data. The instrumentation used during the test consisted of a tri-axial accelerometer and a tri-axial angular rate transducer at the vehicle's c.g. In addition to the c.g. instrumentation, the Geo Metro was instrumented as described in Federal Motor Vehicle Safety Standard (FMVSS) 208.[2] The data from the transducers were recorded by two data acquisition systems: the DSPT onboard data acquisition system (ODAS III) and an umbilical cable tape recorder system. Table 3 describes the

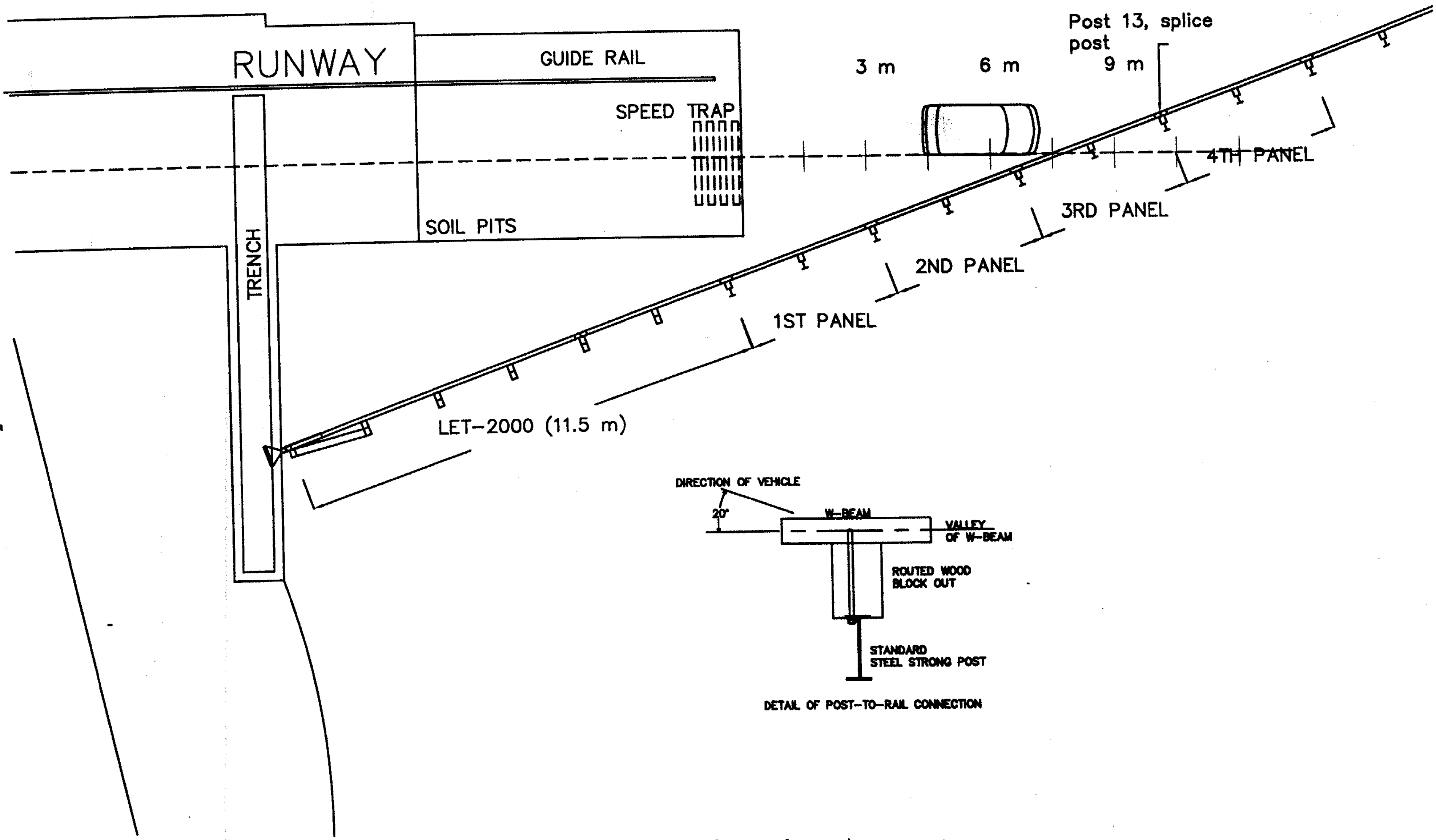


Figure 2. Layout of w-beam barrier system.

recorder system. Table 3 describes the instrumentation used during the test. A three-dimensional sensor location is included in table 3. The location coordinates were referenced from the right-front wheel hub, which was 265 mm above ground.

The ODAS III is a self-contained system. The output from the sensors was filtered, digitally sampled, and digitally stored within the ODAS units mounted directly to the test vehicle inside the occupant compartment. The ODAS III system was factory set with a 4000-Hz analog filter and a digital sampling rate of 12,500 Hz. FMVSS 208 accelerometer data (vehicle component data), c.g., and rate transducer data were collected via the ODAS III system.

The FOIL umbilical cable system utilizes a 90-m cable between the vehicle transducers and a rack of signal conditioning amplifiers. The output from the amplifiers was recorded on 25-mm magnetic tape via a Honeywell 5600E tape recorder. After the test, the tape is played back through anti-aliasing filters (set to 1000 Hz), then input to a Data Translation analog-to-digital converter (ADC). The sample rate was set to 5000 Hz. The umbilical cable system recorded c.g. acceleration data.

Table 3. Summary of instrumentation and channel assignments for test 99F003.

ODAS III onboard data system				
Ch	**Transducer**	**Maximum range**	**Data description**	**Location* (X,Y,Z) mm**
1	Accelerometer	100 g	Vehicle c.g., X-axis	-819,782,106
2	Accelerometer	100 g	Vehicle c.g., Y-axis	-819,782,106
3	Accelerometer	100 g	Vehicle c.g., Z-axis	-819,782,106
4	Accelerometer	2000 g	Top of engine, X-axis	277,684,490
5	Accelerometer	2000 g	Bottom of engine, X-axis	115,757,-17
6	Accelerometer	2000 g	Left front caliper,X-axis	106,1390,26
7	Accelerometer	2000 g	Right front caliper,X-axis	107,152,25
8	Accelerometer	2000 g	Instrument panel, X-axis	-396,773,652

9	Rate transducer	500 °/s	Pitch rate, c.g.	-819,782,106
10	Rate transducer	500 °/s	Roll rate, c.g.	-819,782,106
11	Rate transducer	500 °/s	Yaw rate, c.g.	-819,782,106
Umbilical cable, tape recorder system.				
1	Accelerometer	100 g	Vehicle c.g., X-axis	-819,782,106
2	Accelerometer	100 g	Vehicle c.g., Y-axis	-819,782,106
3	Accelerometer	100 g	Vehicle c.g., Z-axis	-819,782,106
11	Contact switch	1.5 V	Time of impact, T0	Not available
12	Contact switches	1.5 V	Runway speed trap	Not available
14	Generator	1.5 V	1 kHz reference signal	Not available
* Origin located at right front wheel hub (265 mm above ground)				

<u>High-speed photography.</u> The crash test was photographed using 10 high-speed cameras with an operating speed of 500 frames/s. All high-speed cameras used Kodak 2253 daylight film. In addition to the high-speed cameras, one real-time camera loaded with Kodak 7239 daylight film and two 35-mm still cameras were used to document the test. Table 4 summarizes the cameras used and their respective placements. The camera numbers listed in table 4 are shown in figure 3.

Table 4. Summary of camera placement.

Camera number	Type	Film speed frames/s	Lens (mm)	Location
1	LOCAM II	500	10	Overhead
2	LOCAM II	500	5.7	On-board, in vehicle
3	LOCAM II	500	50	Left side 90° to impact
4	LOCAM II	500	100	Upstream, view behind rail

Table 4. Summary of camera placement (continued).				
Camera number	Type	Film speed frames/s	Lens (mm)	Location
5	LOCAM II	500	25	Upstream behind rail 45°
6	LOCAM II	500	45	Right side behind rail
7	PHOTEC	500	45	Right side behind rail
8	LOCAM II	500	25	Right side behind rail
9	LOCAM II	500	150	Behind rail in line with vehicle trajectory
10	LOCAM II	500	100	In line with rail downstream, view backside
11	BOLEX	24	ZOOM	Documentary
12	CANNON A-1	still	ZOOM	Documentary
13	CANNON A-1	still	ZOOM	Documentary

DATA ANALYSIS

Data were collected via the FOIL analog tape recorder system, including speed-trap data, the FOIL ODAS III on-board data system, and high-speed film.

Speed trap. As the vehicle passed over the speed-trap tape switches, electronic pulses were recorded to analog tape. The tape was played back through a Data Translation ADC inside a desktop computer. The time between pulses was then determined using the software provided with the ADC. The time intervals between the first pulse and each of the subsequent four pulses together with the distances between corresponding tape switches were entered into a computer spreadsheet and a linear regression was performed to determine the best-line fit of the data points. The impact velocity was then determined from the slope of the best-line fit of the displacement vs. time curve.

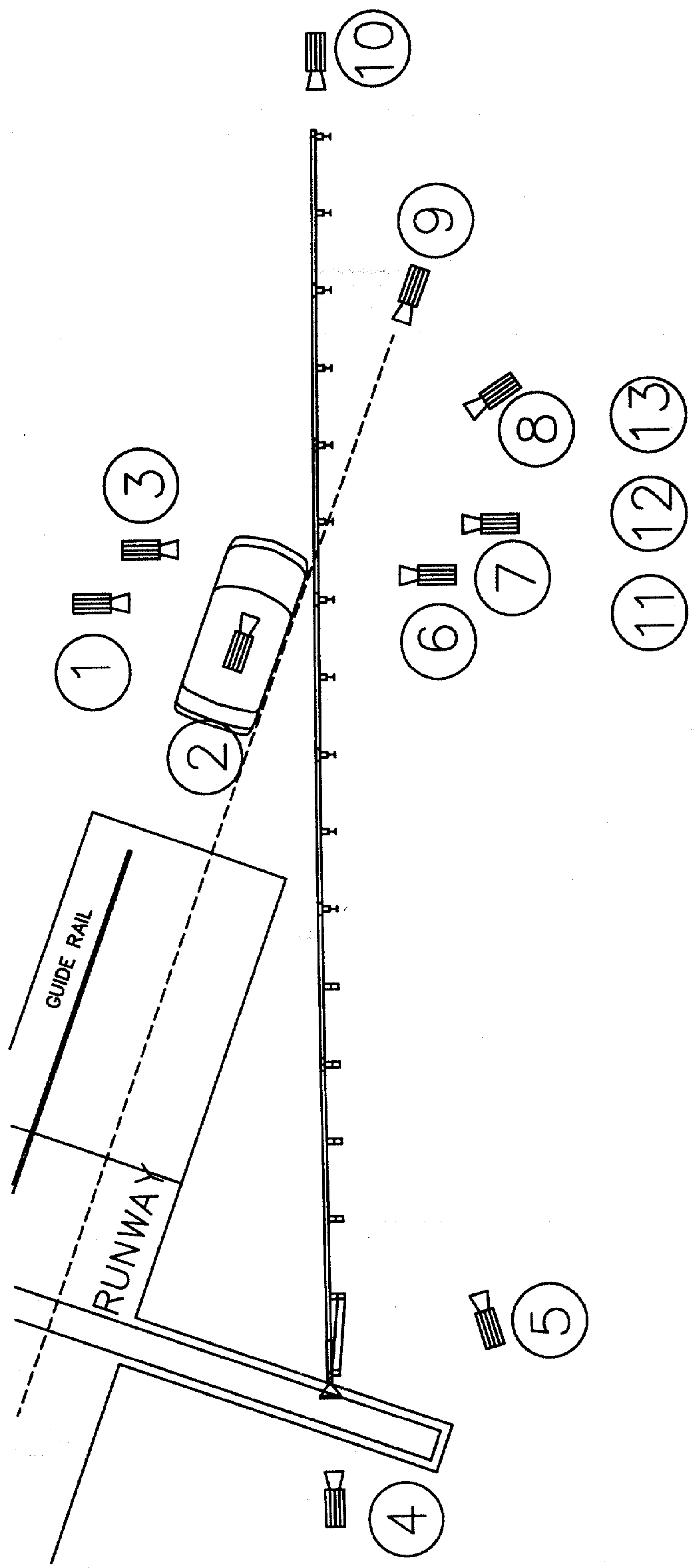


Figure 3. Camera placement, test 99F003.

Transducer data package. After the test, data from both data systems were converted to digital format and stored. The digital data from the tape recorder system and the ODAS III system were converted to the ASCII format, the zero bias was removed, and the data were digitally filtered using a digital Butterworth low-pass filter. The data from the crash tests were digitally filtered with a cutoff frequency of 300 Hz. The data were transferred to a spreadsheet for analysis.

The longitudinal c.g. acceleration data were integrated twice to produce velocity and displacement traces. Using techniques outlined in *NCHRP Report 350* the occupant risk values were determined. Acceleration vs. time traces were plotted for all FMVSS 208 accelerometers.

High-speed photography. The crash event was recorded on 16-mm film by 10 high-speed cameras. The film from the camera perpendicular to the vehicle trajectory, with a 50-mm lens, was analyzed for initial vehicle velocity. The overhead camera film was analyzed to determine vehicle and rail displacement after contact. The overhead camera was also used to verify the impact location, impact angle, exit angle, and exit speed. Analysis was performed using an NAC Film Motion Analyzer model 160-F in conjunction with a desktop personal computer. The motion analyzer digitized the 16-mm film, reducing the image to Cartesian coordinates. The Cartesian coordinate data were then imported into a computer spreadsheet for analysis. Using the Cartesian coordinate data, a displacement vs. time history was obtained. A linear regression was performed on the first 20 data points of the displacement vs. time traces to verify the vehicle's impact velocity. The film was used to verify data obtained from the speed trap and rate transducer and could be used in the event of transducer malfunction. The film was used to observe roll, pitch, and yaw angular displacements. The speed trap and accelerometer data were the primary data systems.

RESULTS

The Geo Metro was positioned on the runway and attached to the FOIL propulsion system. The windows were up, the emergency brake was released, and the ignition was in the "on" position arming the air-bags. The vehicle was accelerated to 99.0 km/h prior to striking the modified G4(1s) barrier system. The vehicle struck the guardrail at 20.5°. The vehicle made first contact with the guardrail within 50 mm of the intended location midway between posts 11 and 12. The vehicle began to redirect away from the barrier a few milliseconds after initial contact. The vehicle continued forward turning to the left. The right front tire and wheel did not make contact at post 12. The vehicle remained in contact with the rail as it continued to deflect the rail backwards. As the vehicle approached post 13

the right front tire and lower half of the w-beam rail rubbed. The deflection of the rail allowed the right front wheel to graze post 13 at 0.120 s. The tire rim struck the post along the bead of the tire causing to tire to deflate. The counter-clockwise yaw induced by the rail caused the dummy (located in the right front seat) to lean to the right and strike the window. The window shattered when the dummy's head made contact at 0.116 s. The dummy fell back toward the left and came to rest on its left side in the driver seat. The vehicle exited the rail at 6° and at approximately 83 km/h. The contact between the vehicle and barrier system was not significant enough to deploy the air-bags. The vehicle continued into the FOIL run-out area and the brakes were applied. The vehicle remained stable and upright and did not turn back toward the barrier. The vehicle came to rest 69 m downstream from the impact location. Figure 4 summarizes the results from the modified G4(1s) barrier test. Appendix A contains photographs of the pre- and post-test environments. Table 5 lists the maximum and minimum peak values obtained from the vehicle accelerometers. The values listed are Class 180 data (digital filter cut-off frequency of 300 Hz). Appendix B contains data plots of the data collected from each vehicle sensors and velocity and displacement data plots for the longitudinal and lateral c.g. accelerometers. All acceleration data plots are from Class 180 data.

Table 5. Maximum and minimum peak values recorded.

Location	**Peak Acceleration (g's)**	
	Max (+)	**Max (-)**
Top of engine	6.4	9.9
Bottom of engine	203.2	NA
Left control arm	28.9	13.2
Right control arm	44.5	78.8
Instrument panel	19.6	48.3
C.g. X-axis	4.8	10.9
C.g. X-axis, redundant	4.8	10.4
C.g. Y-axis	5.3	16.5
C.g. Y-axis, redundant	6.0	16.7
C.g. Z-axis	8.8	8.5
C.g. Z-axis, redundant	10.2	10.0

Occupant responses. The longitudinal and lateral occupant impact velocities (OIV) were determined to be 5.5 m/s and 6.6 m/s, respectively, and they occurred 0.201 s and 0.113 s after initial contact between the vehicle and the barrier. The OIV values are below limits specified in *NCHRP Report 350*. The longitudinal and lateral ridedown accelerations were also below the limits specified and were determined to be 2.1 g's and 8.2 g's, respectively.

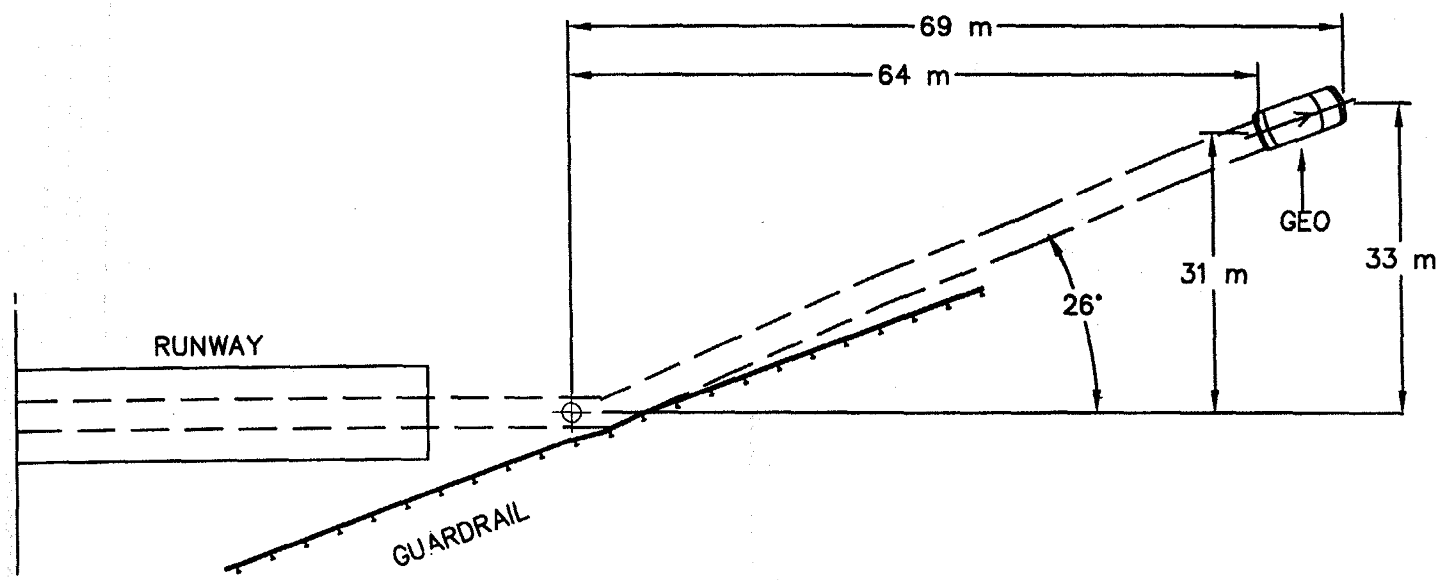
Vehicle damage. The damage to the Geo Metro ranged from cosmetic to significant. The right front corner damage consisted of bumper, headlight, and fender damage. The right front tire was flat and the tire rim was bent. Although the wheel connection to the vehicle was damaged (rods bent), the wheel remained attached to the vehicle. The sideswipe type of collision led to damage along the entire length of the vehicle's right side. The sideswipe caused minor denting to the right door and right rear quarter panel. The right window was shattered by the dummy's head and it did not appear as though the window would have shattered by contact with barrier alone without a dummy present in the right front seat.

Barrier damage. Damage to the modified G4(1s) barrier was minor. One or two strong posts and two sections of w-beam rail were damaged and would need replacing. The remainder of the barrier system sustained no damage during the test. The anchorage at each end of the installation remained steadfast with no evidence of movement or becoming looser.

CONCLUSION

The data were successfully collected and the high-speed film successfully taken during the barrier test. The data and film will aid in the development and validation of a Geo Metro FEM and a model of an 820C vehicle colliding with a longitudinal barrier.

The results summarized in figure 4 indicate that the modified G4(1s) w-beam guardrail system met the safety performance criteria outlined in *NCHRP Report 350* (test designation 3-10). The longitudinal and lateral OIV and ridedown accelerations were below the specified limits. The film and data revealed minor wheel snagging at post 13. The tire grazed the post and was deflated as the tire rim was bent along the tire bead. The snagging was not significant enough to pose a threat to vehicle stability. The vehicle was smoothly redirected by the guardrail barrier. The dynamic rail deflection was 325 mm. The vehicle did not penetrate or form a pocket in the barrier. The vehicle maintained stability and did not develop high degrees of roll or pitch. The vehicle exited the rail at 6° (30 percent of impact angle) and the vehicle maintained its trajectory not appearing to intrude into adjacent traffic.



Test location..............................FHWA FOIL
Test number..................................99F003
Date..............................April 8, 1999
Test designation..............NCHRP 350 test 3-10
Test device......Modified G4(1s) guardrail barrier
Posts......Standard W150 x 12.5 kg/m steel posts
Offset block.....150 by 200 by 355 mm wood block
W-beam rail..........Standard 12 ga. steel panel
Anchorage (upstream)...................LET 2000
Anchorage (downstream)................blunt-end
Total length of barrier....................42 m
Foundation...........placed at end of FOIL runway

Vehicle............................1997 Geo Metro
Weight: Inertial....................833 kg
Gross........................908 kg
Dummy........................75 kg
Impact speed..........................100.5 km/h
Impact location........... between post 11 and 12
Impact angle...............................20.5°

Occupant Risk:	Observed	Design/Limit
Longitudinal:		
Occupant delta V at 0.6 m	5.5 m/s	9/12 m/s
Ridedown acceleration	2.1 g's	15/20 g's
Lateral:		
Occupant Delta V at 0.3 m	6.5 m/s	9/12 m/s
Ridedown acceleration	8.2 g's	15/20 g's

Peak 50 ms acceleration:
Longitudinal................................ 4.5 g's
Lateral.....................................8.2 g's
Vehicle Damage:
Traffic Accident Data (TAD)..................01-RD-3
Vehicle Damage Index (VDI)..................61RDES2
Rail deflection:
Static......................................200 mm
Dynamic.....................................325 mm
Exit speed...................................83 km/h
Exit angle......................................6.0°

Figure 4. Summary of results, test 99F003.

APPENDIX A. TEST PHOTOGRAPHS 99F003

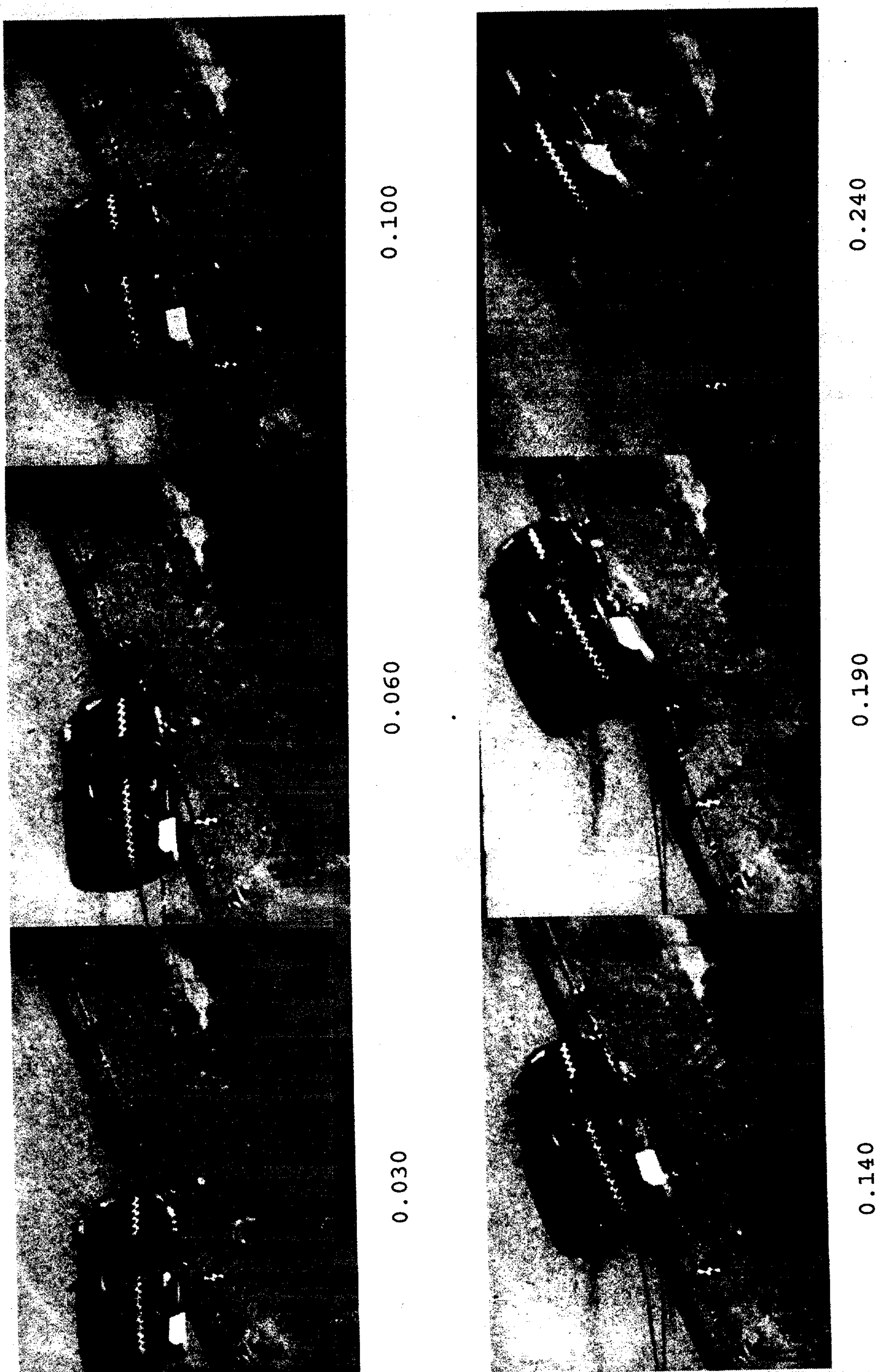


Figure 5. Photographs during the test, test 99F003.

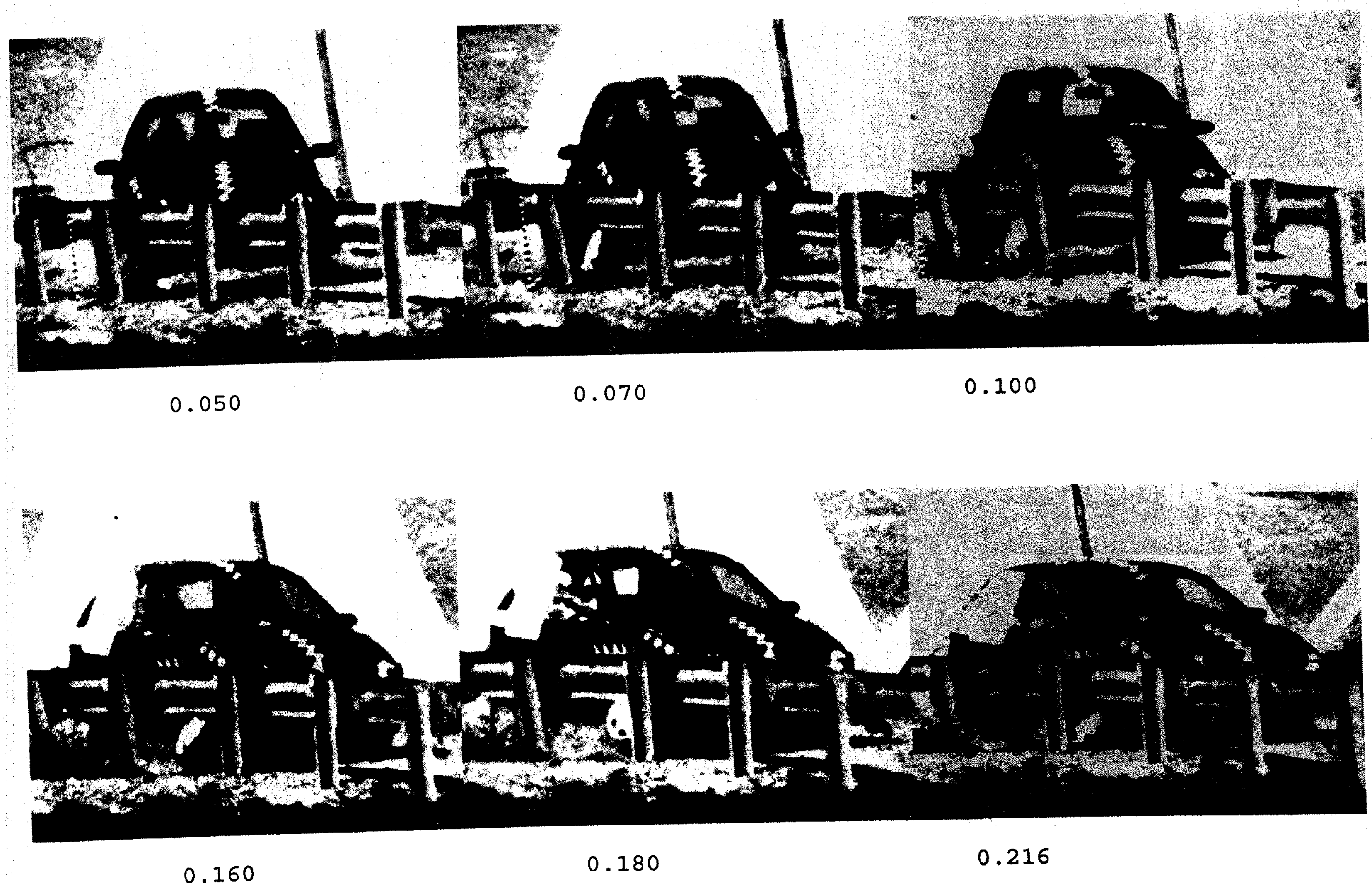


Figure 6. Additional photographs during the test, test 99F003.

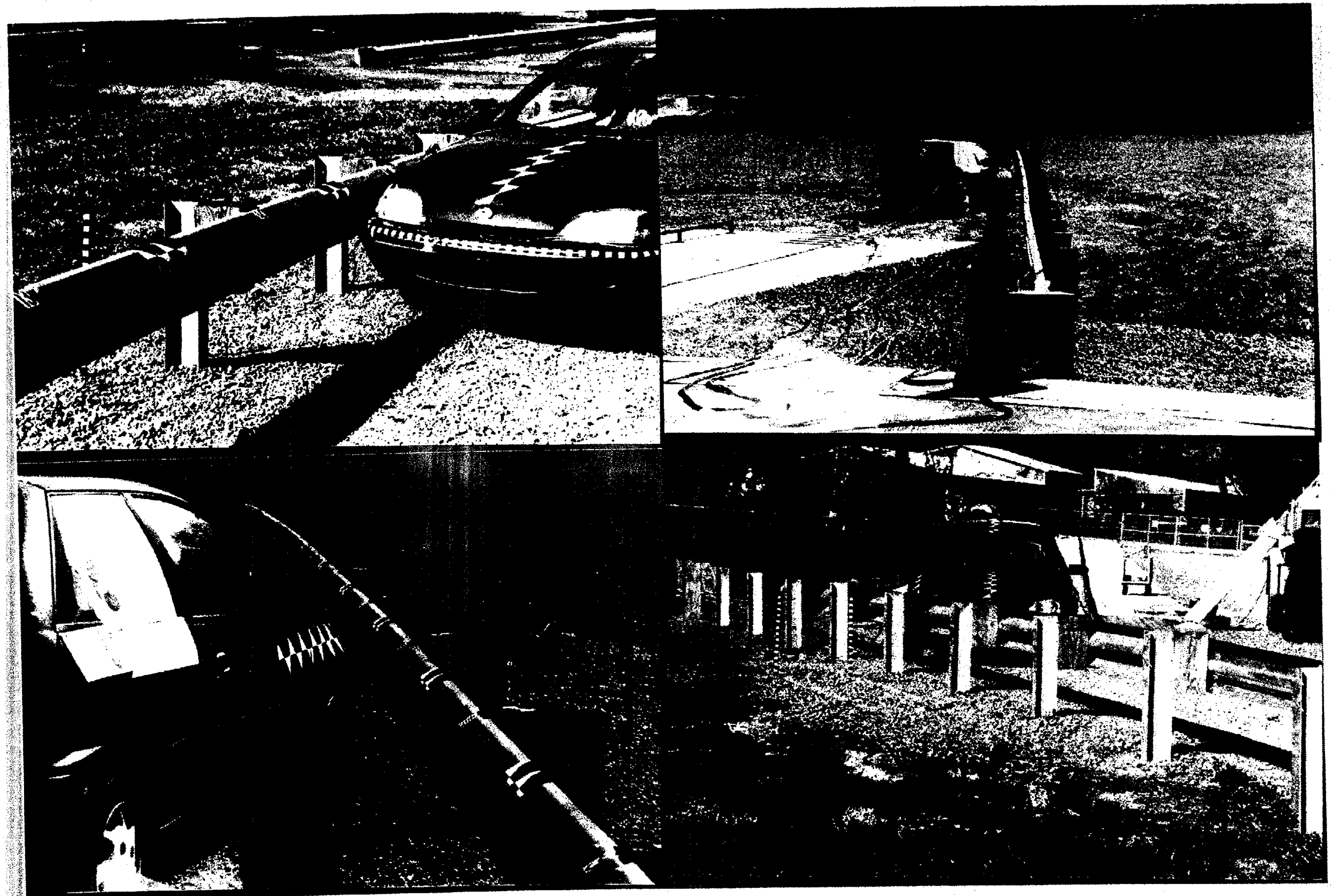


Figure 7. Pre-test photographs, test 99F003.

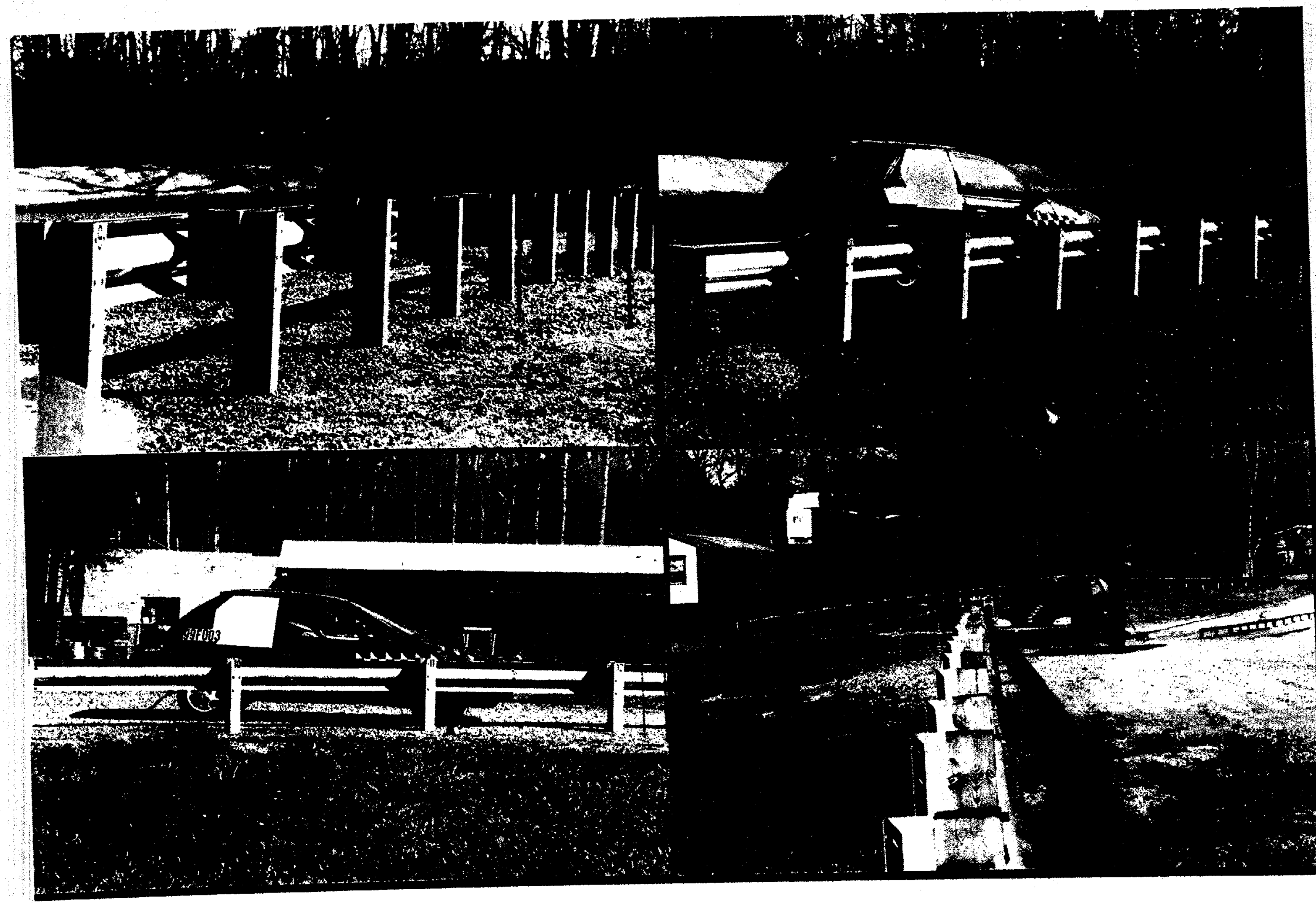


Figure 8. Additional pre-test photographs, test 99F003.

Figure 9. Post-test photographs, test 99F003.

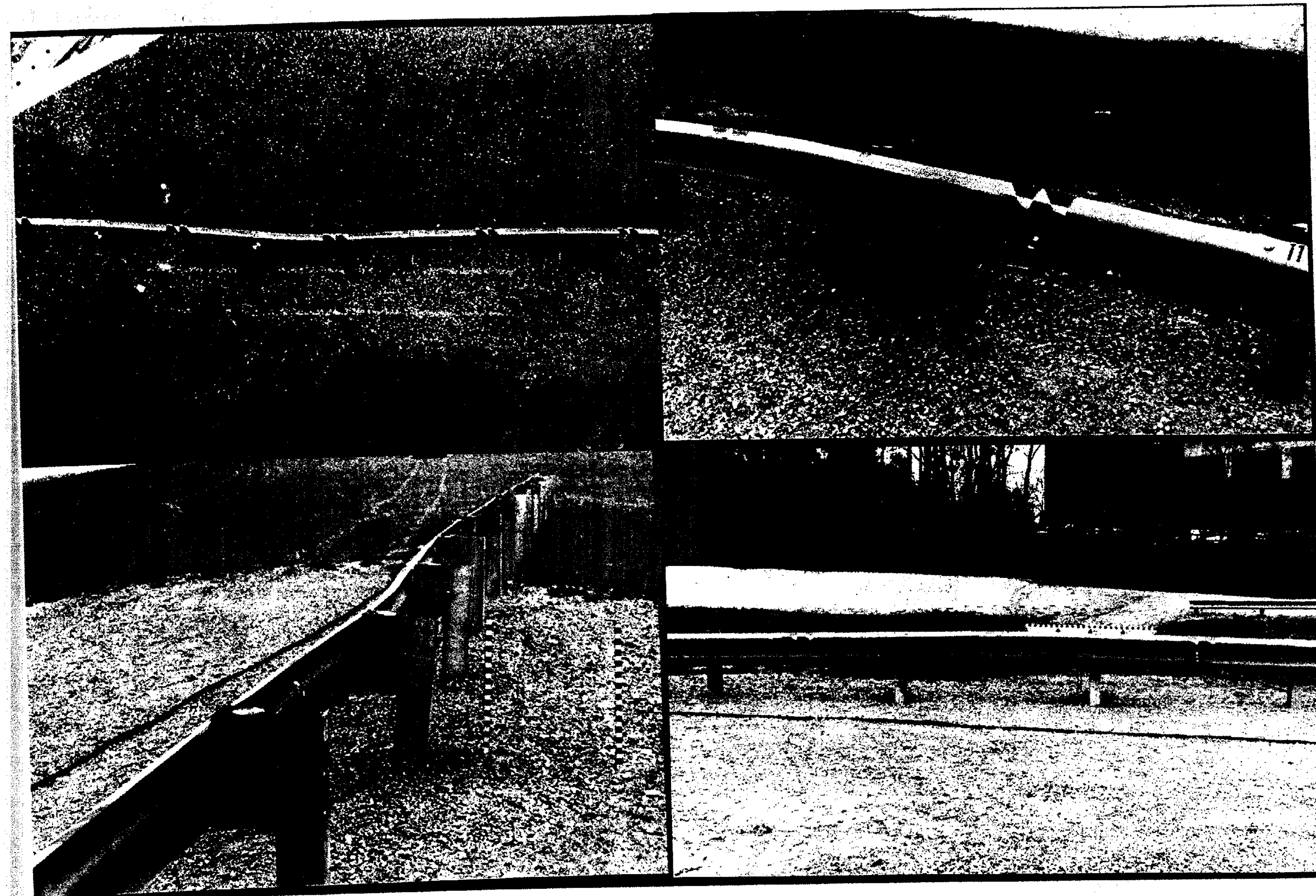


Figure 10. Post-test photographs continued, test 99F003.

Figure 11. Additional post-test photographs, test 99F003.

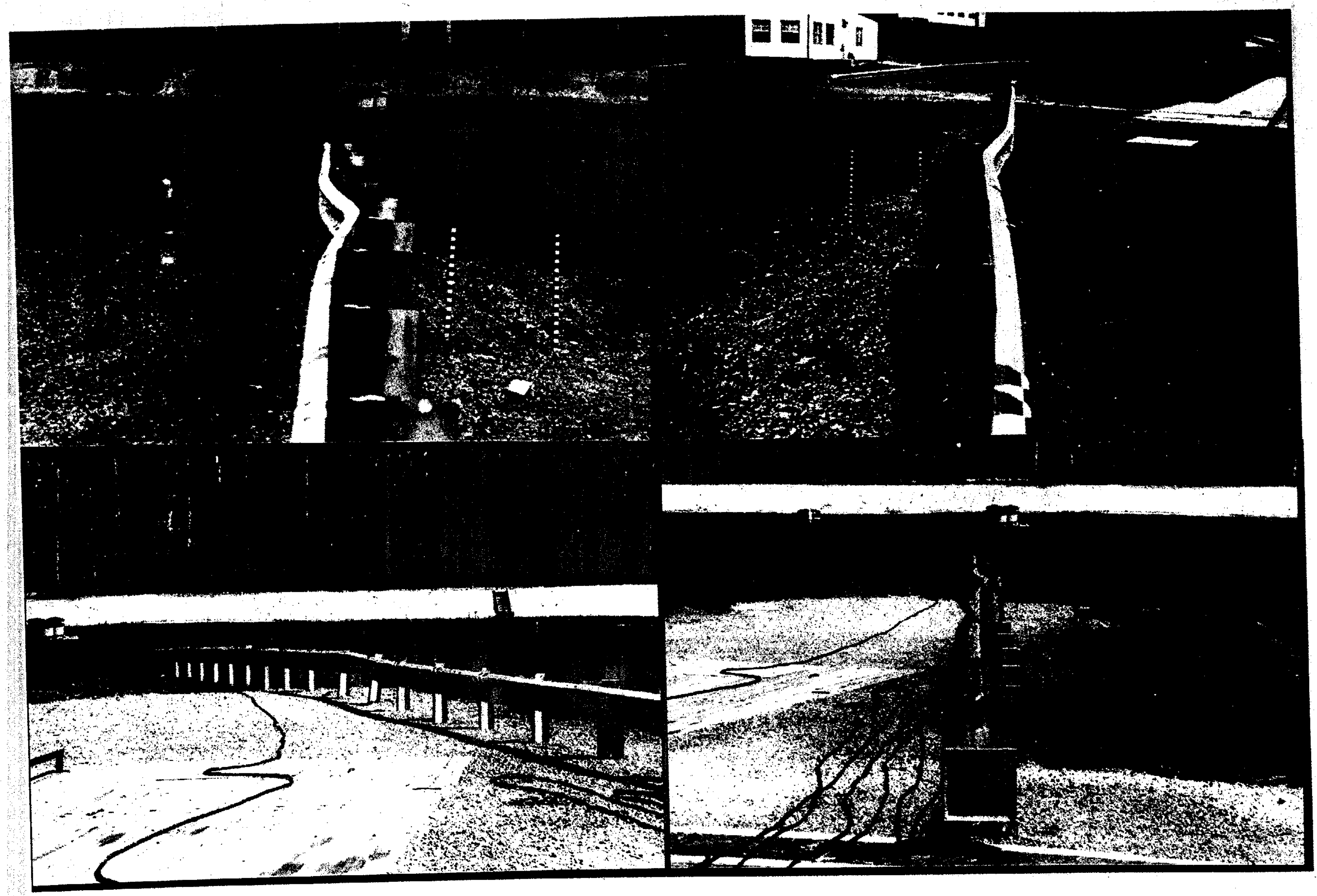


Figure 12. Additional post-test photographs continued, test 99F003.

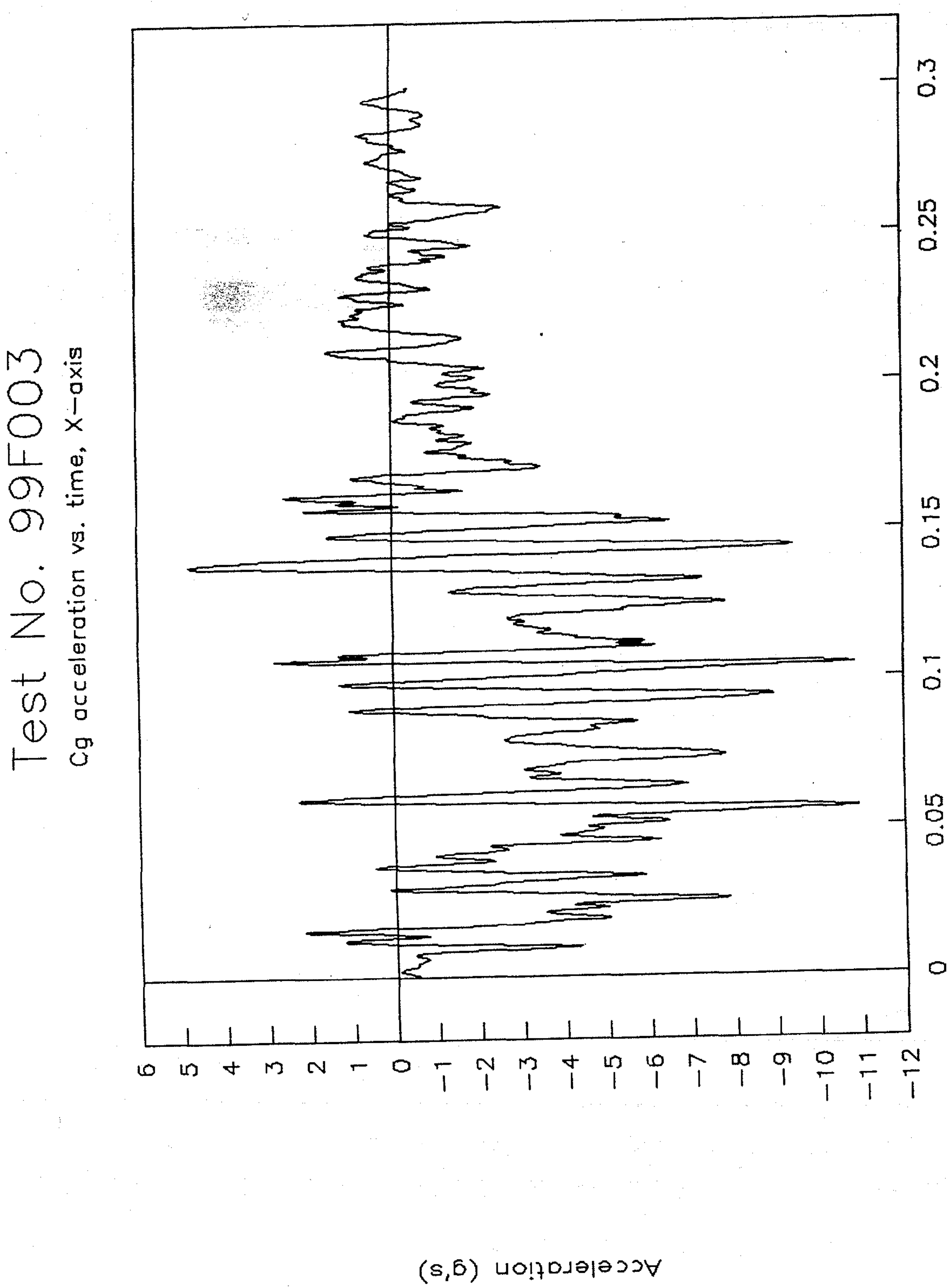


Figure 13. C.g. acceleration vs. time, X-axis, test 99F003.

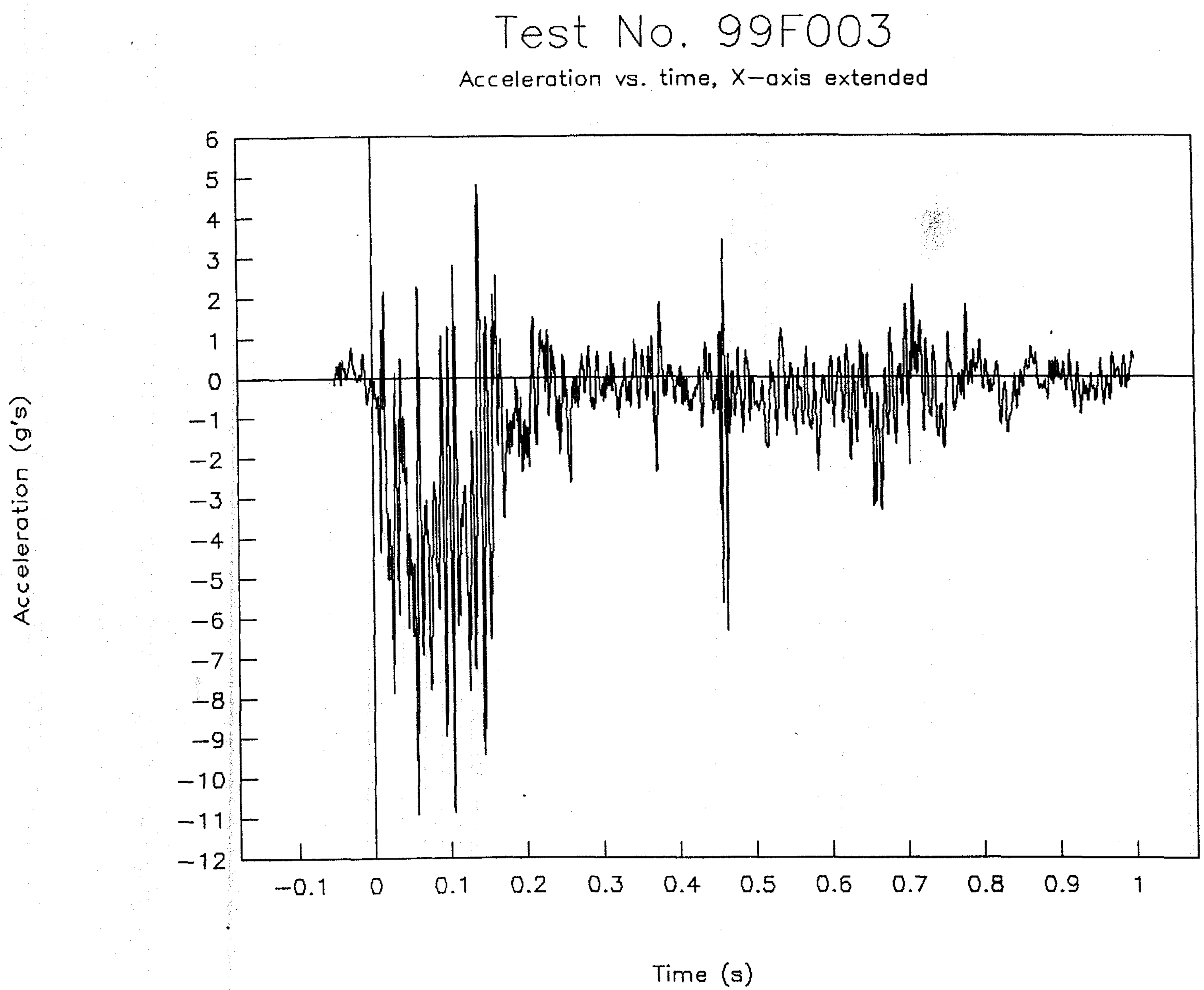


Figure 14. C.g. acceleration vs. time, X-axis extended, test 99F003.

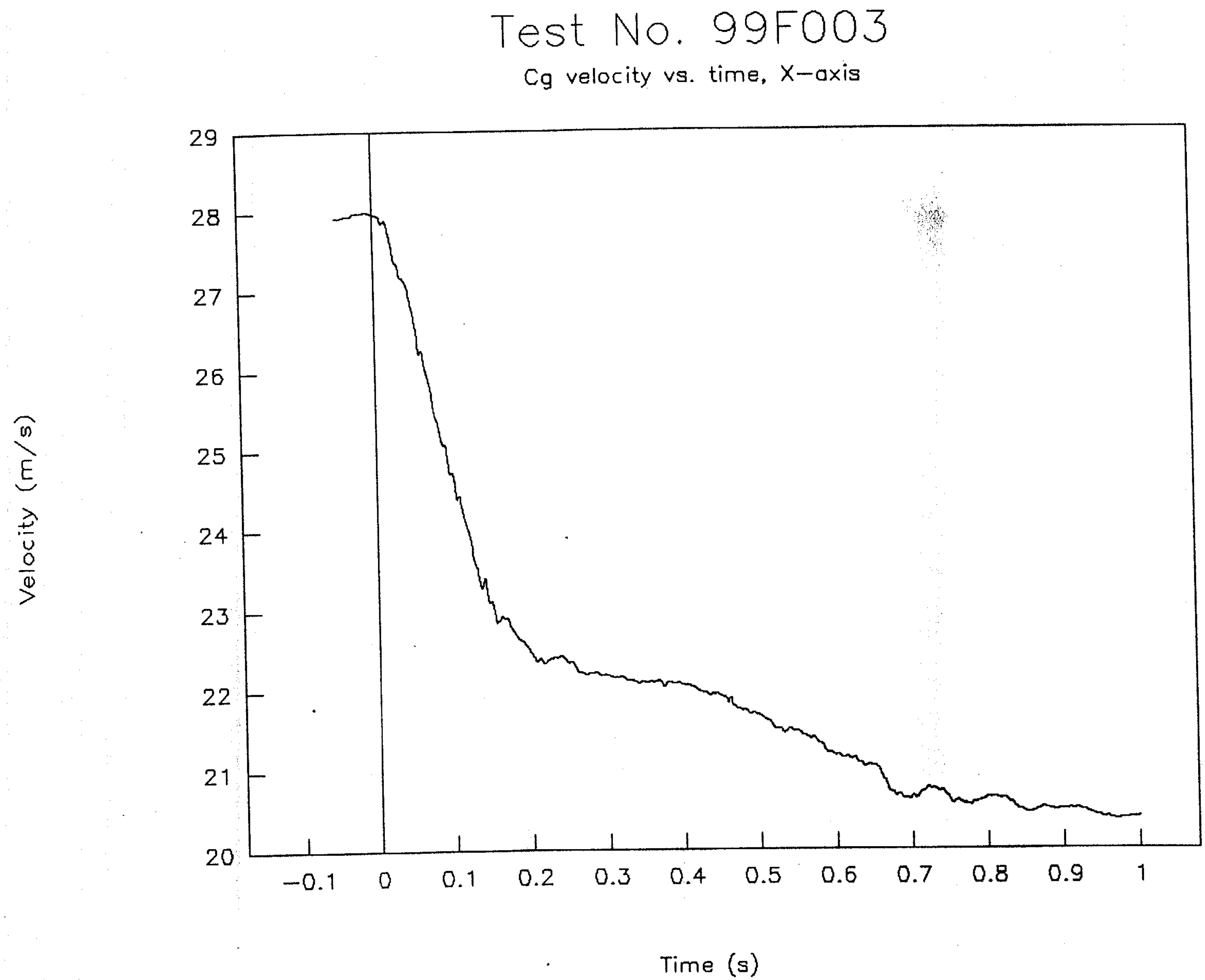


Figure 15. C.g. velocity vs. time, X-axis, test 99F003.

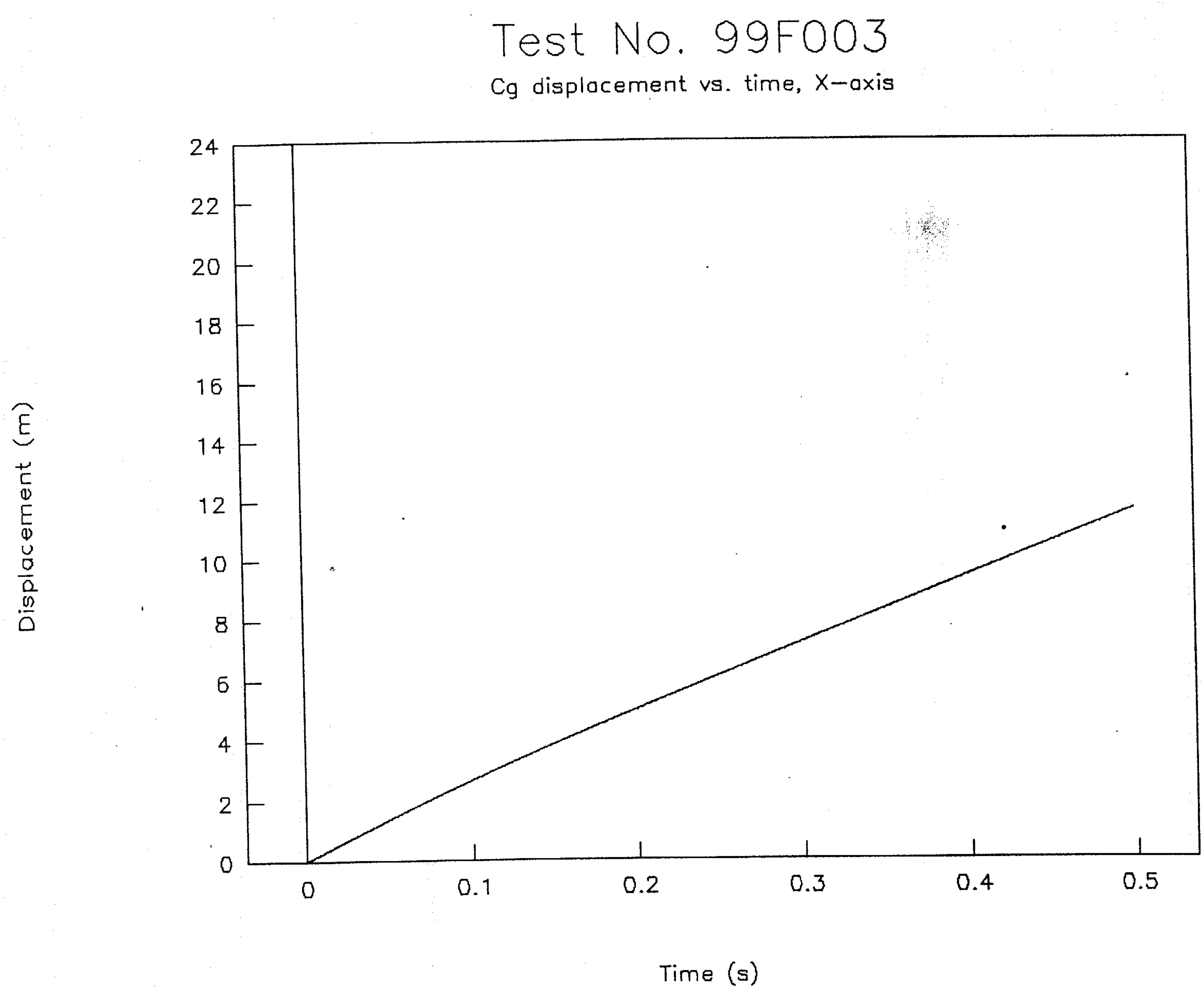


Figure 16. C.g. displacement vs. time, X-axis, test 99F003.

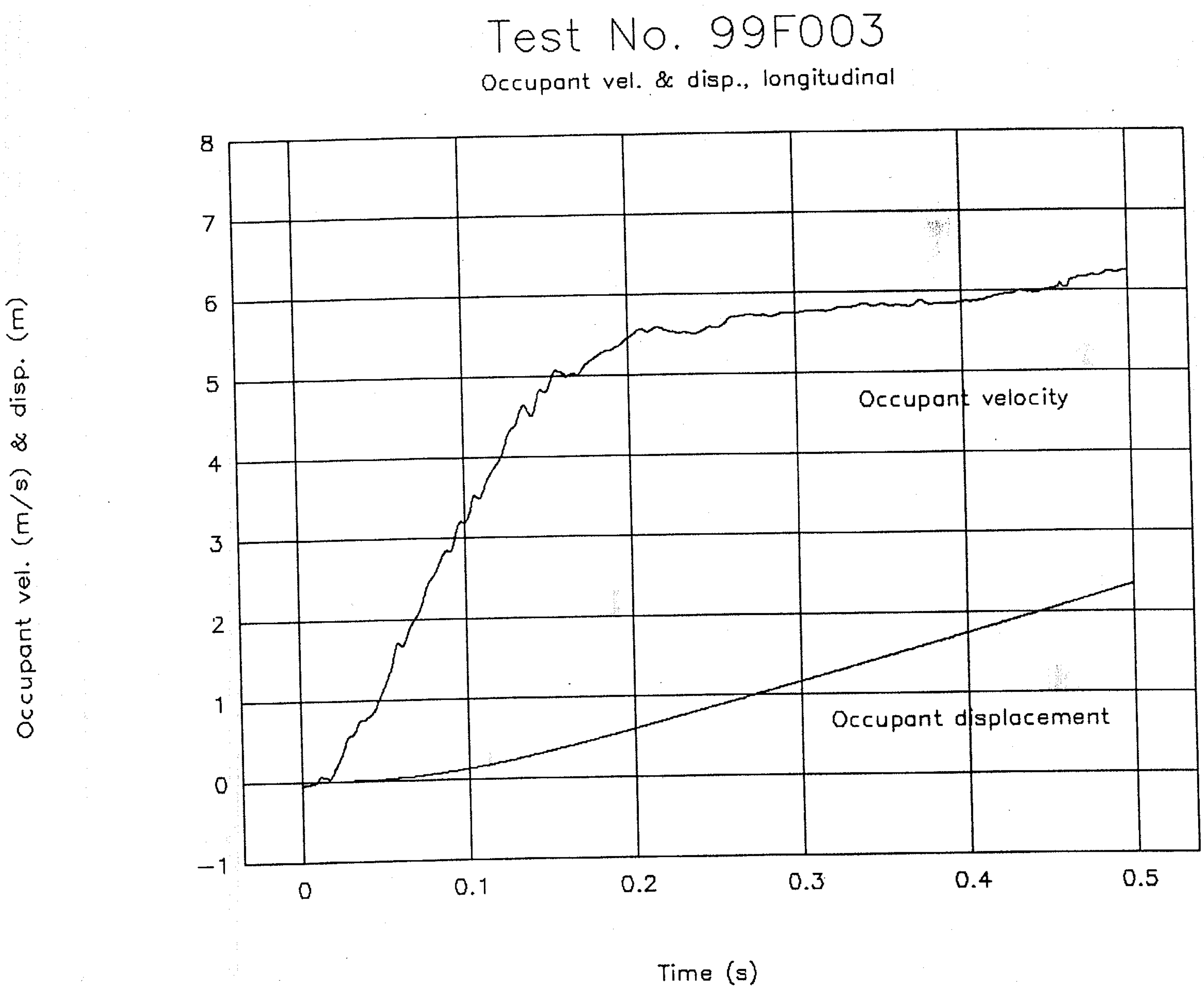


Figure 17. Longitudinal occupant velocity and displacement vs. time, test 99F003.

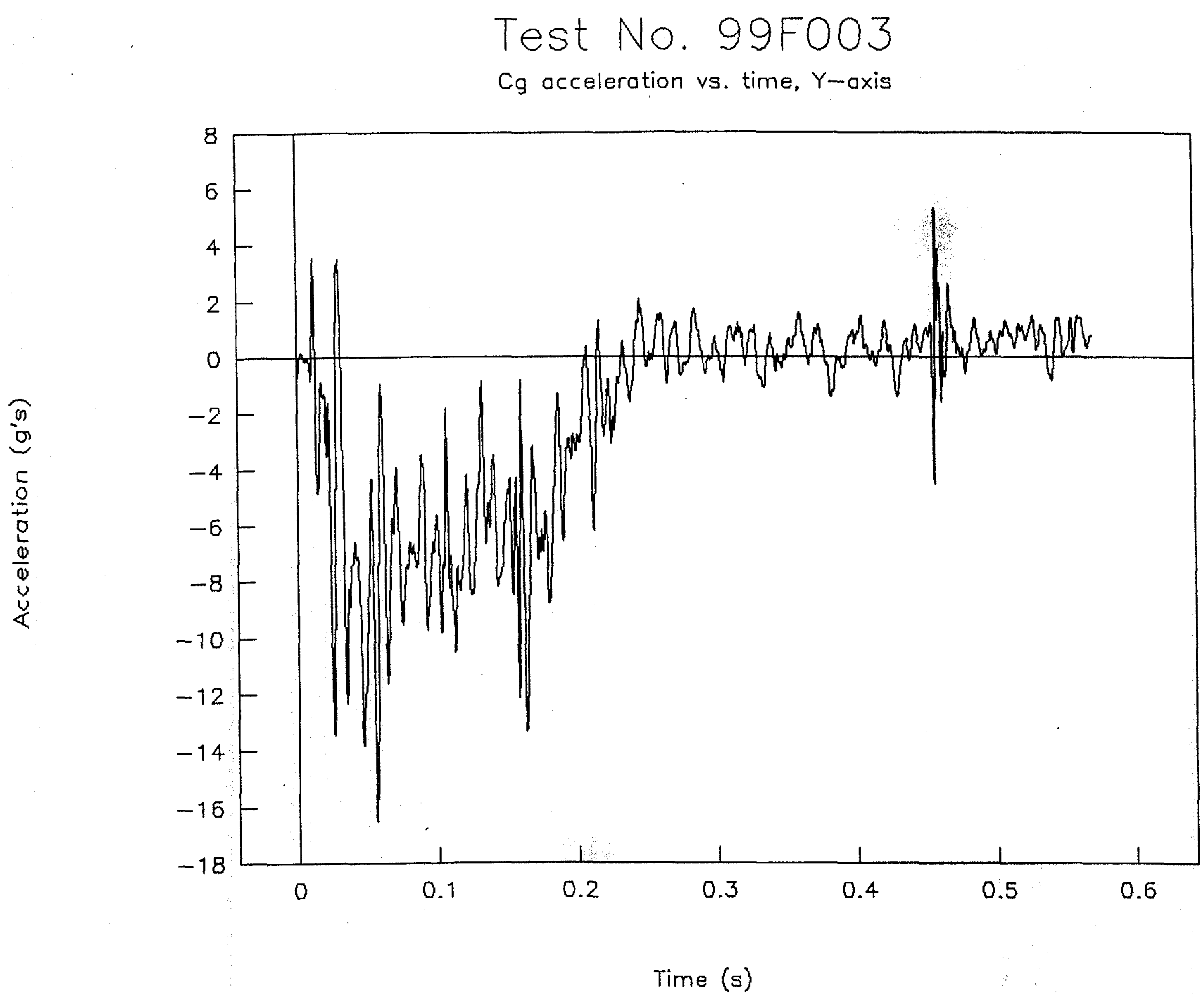


Figure 18. C.g. acceleration vs. time, Y-axis, test 99F003.

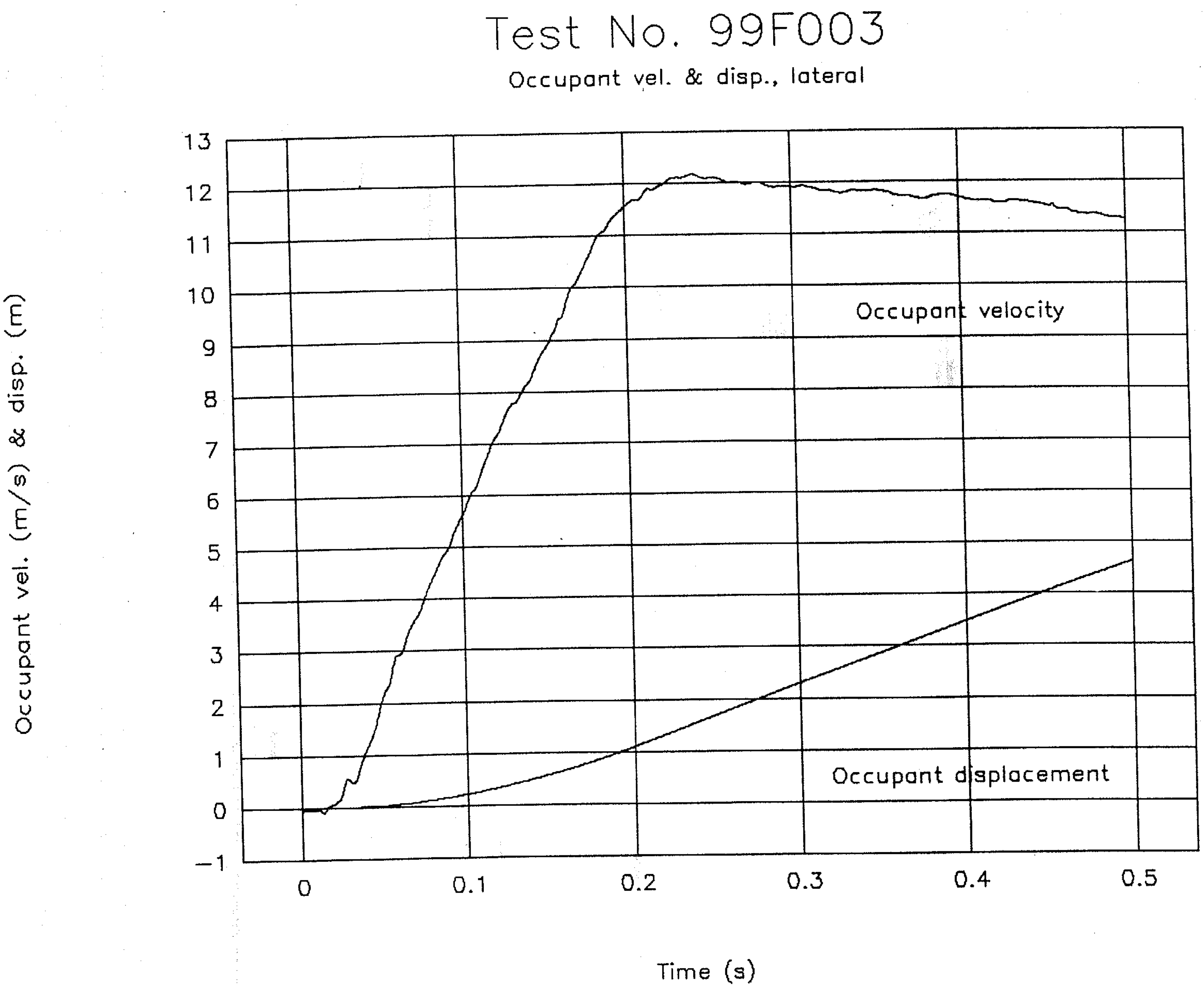


Figure 19. Lateral occupant velocity and displacement vs. time, test 99F003.

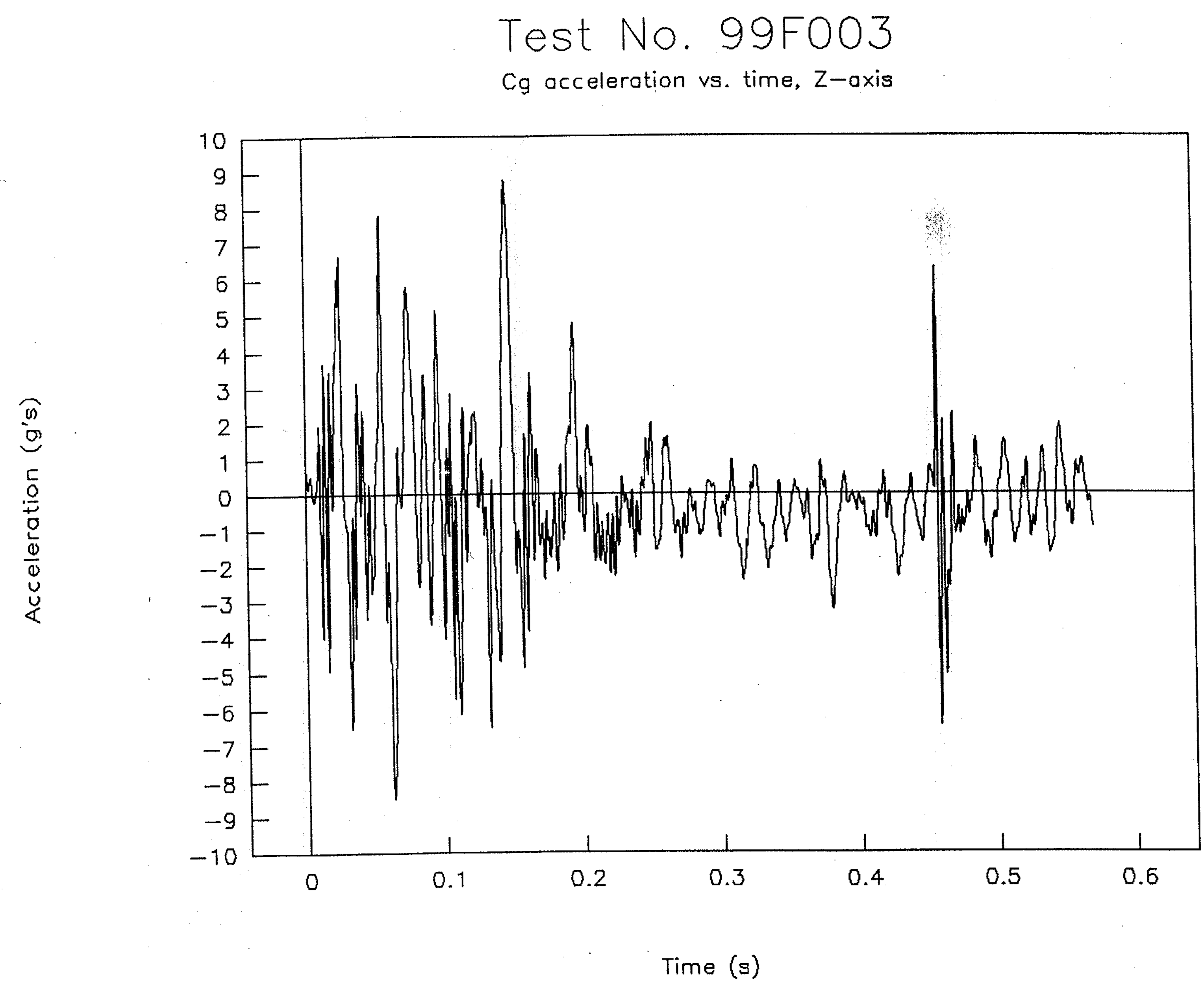


Figure 20. C.g. acceleration vs. time, Z-axis, test 99F003.

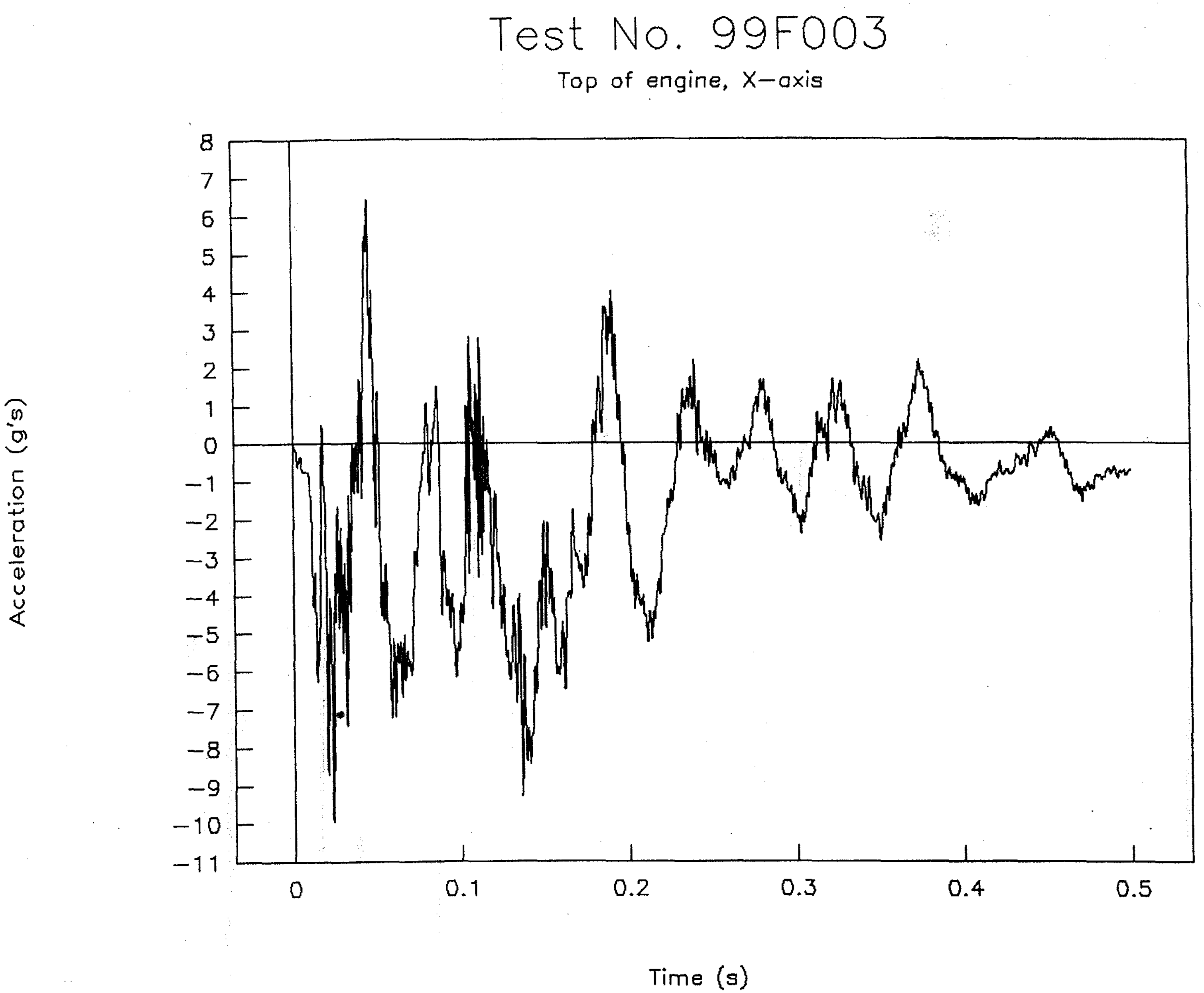


Figure 21. Top of engine acceleration vs. time, X-axis, test 99F003.

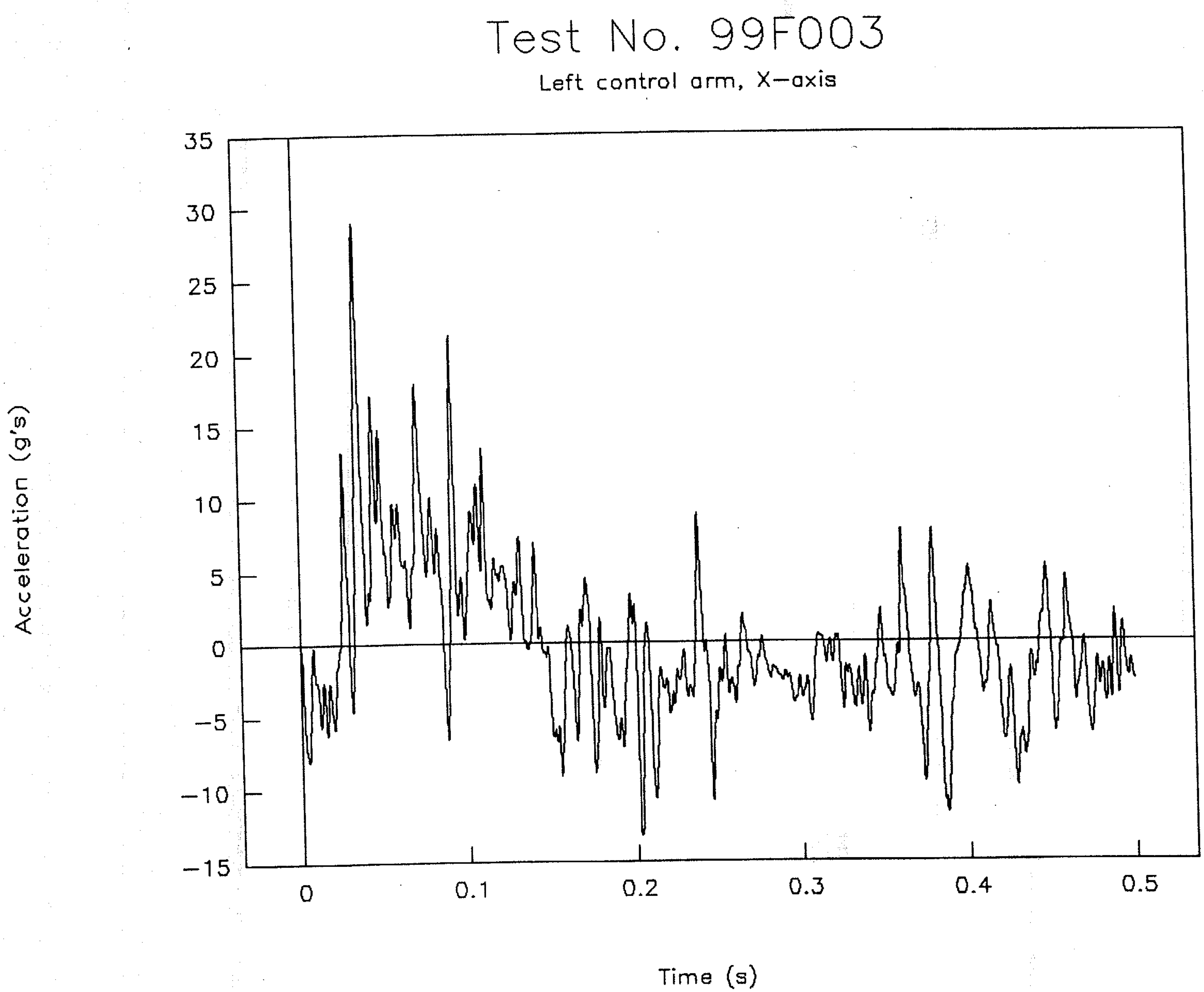


Figure 22. Left control arm acceleration vs. time, X-axis, test 99F003.

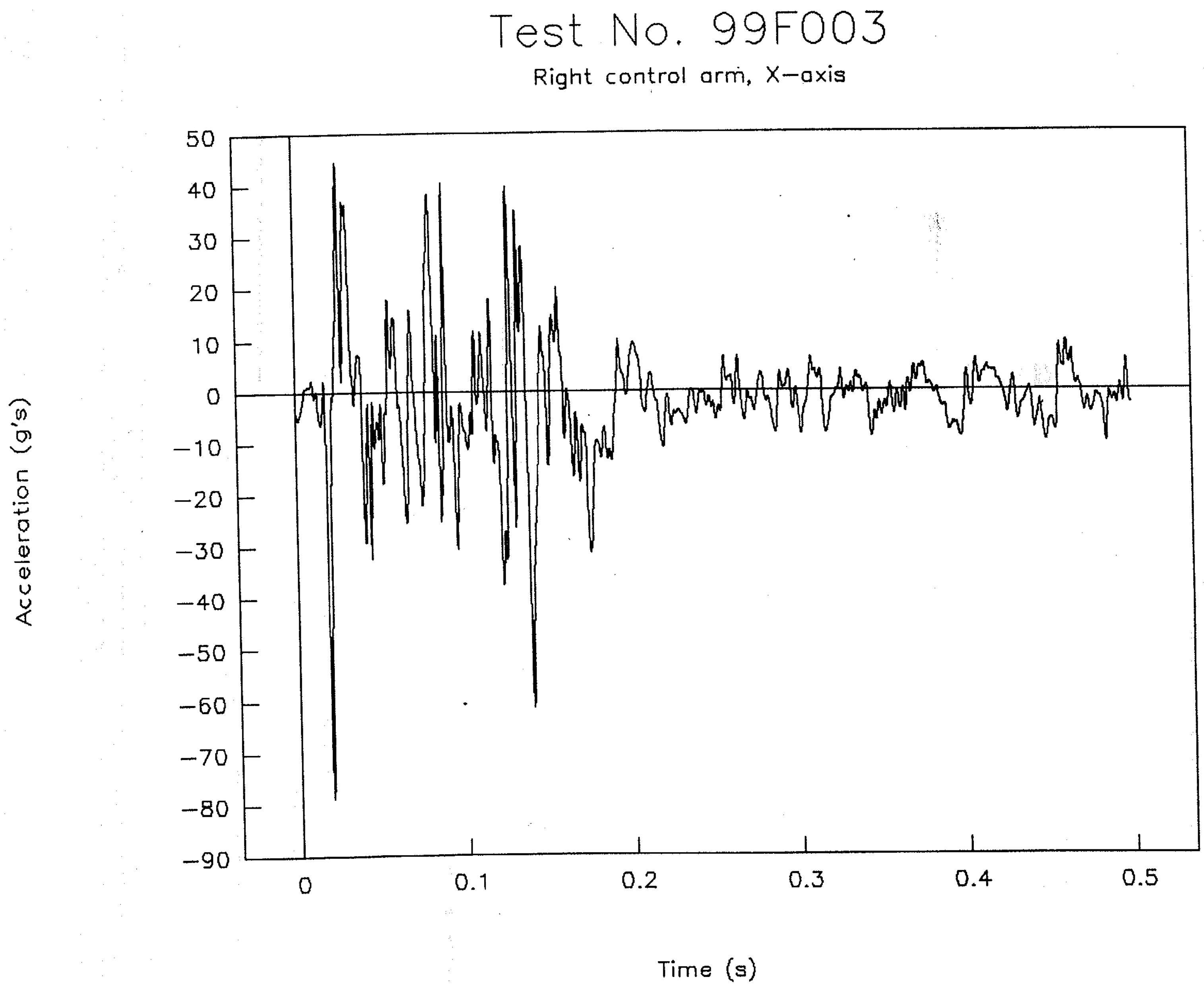


Figure 23. Right control arm acceleration vs. time, X-axis, test 99F003.

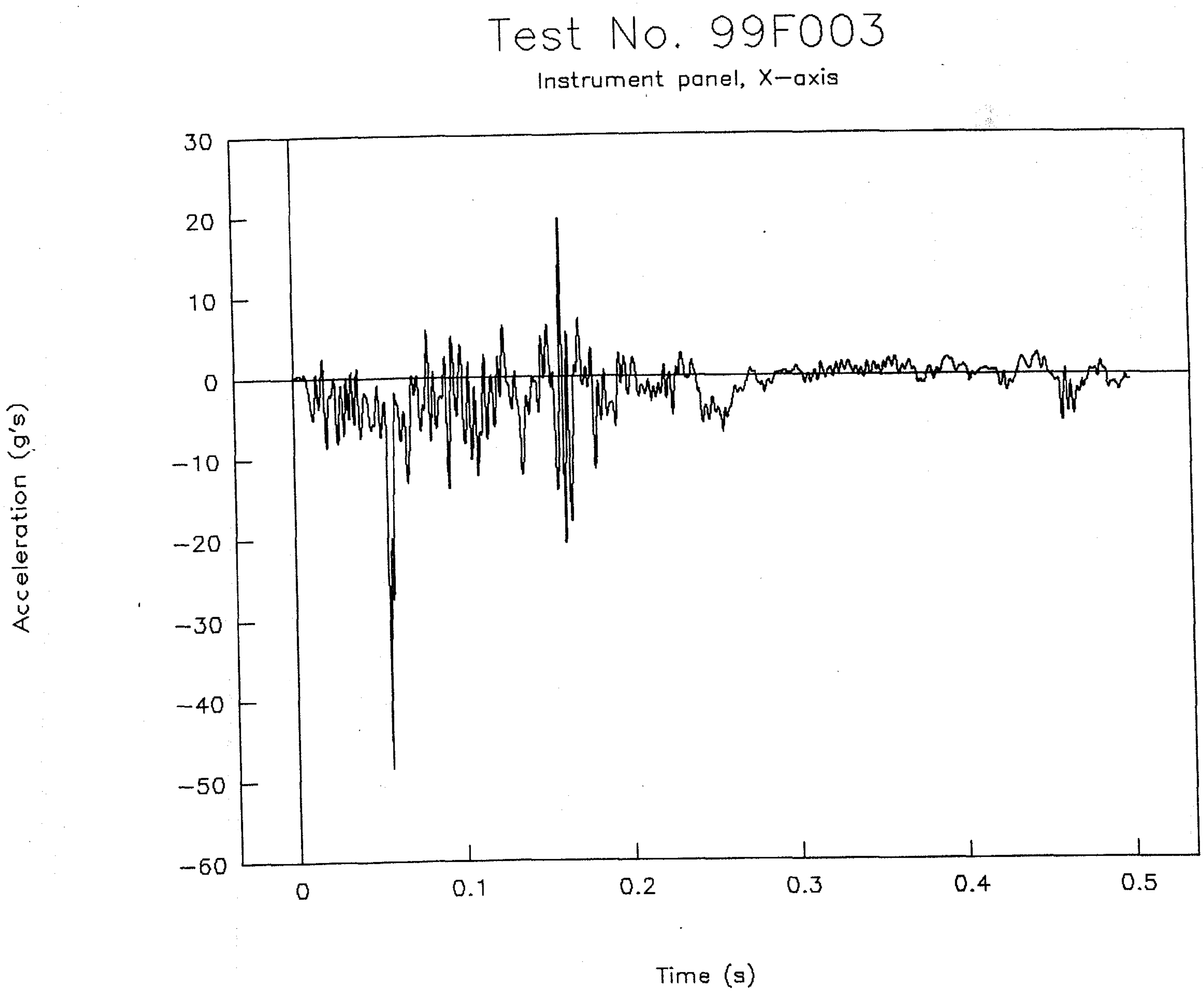


Figure 24. Instrument panel acceleration vs. time, X-axis, test 99F003.

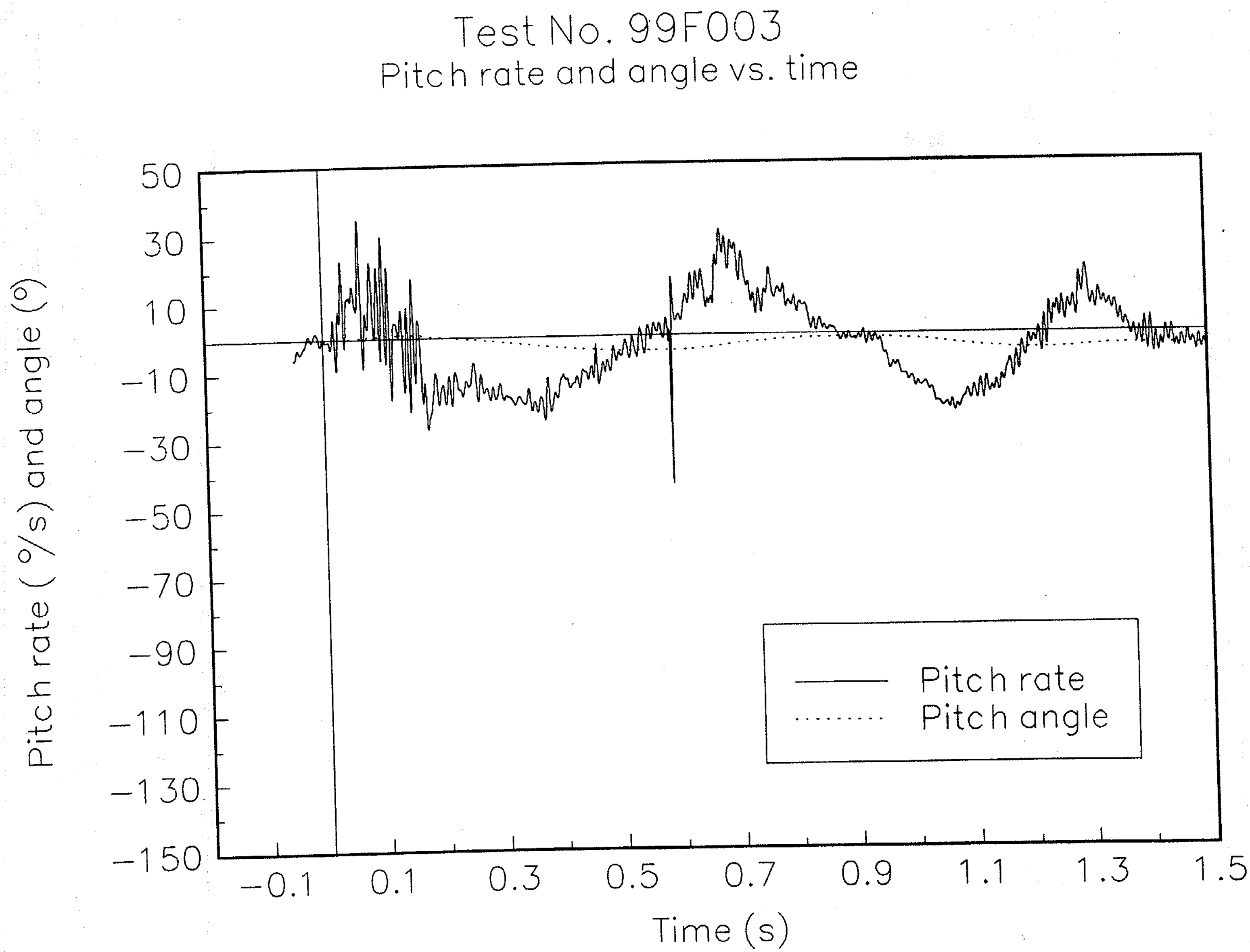


Figure 25. Pitch rate and angle vs. time, test 99F003.

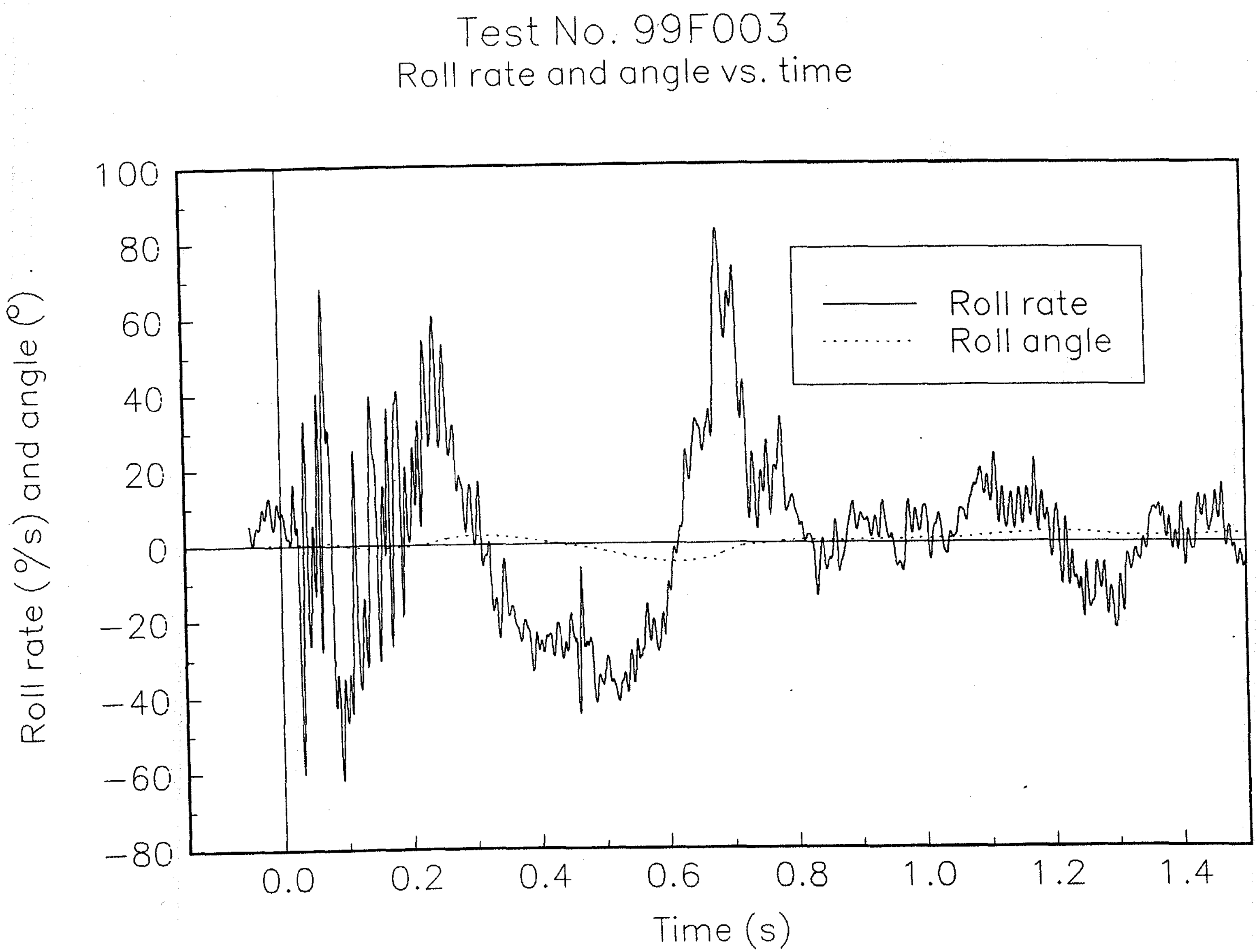


Figure 26. Roll rate and angle vs. time, test 99F003.

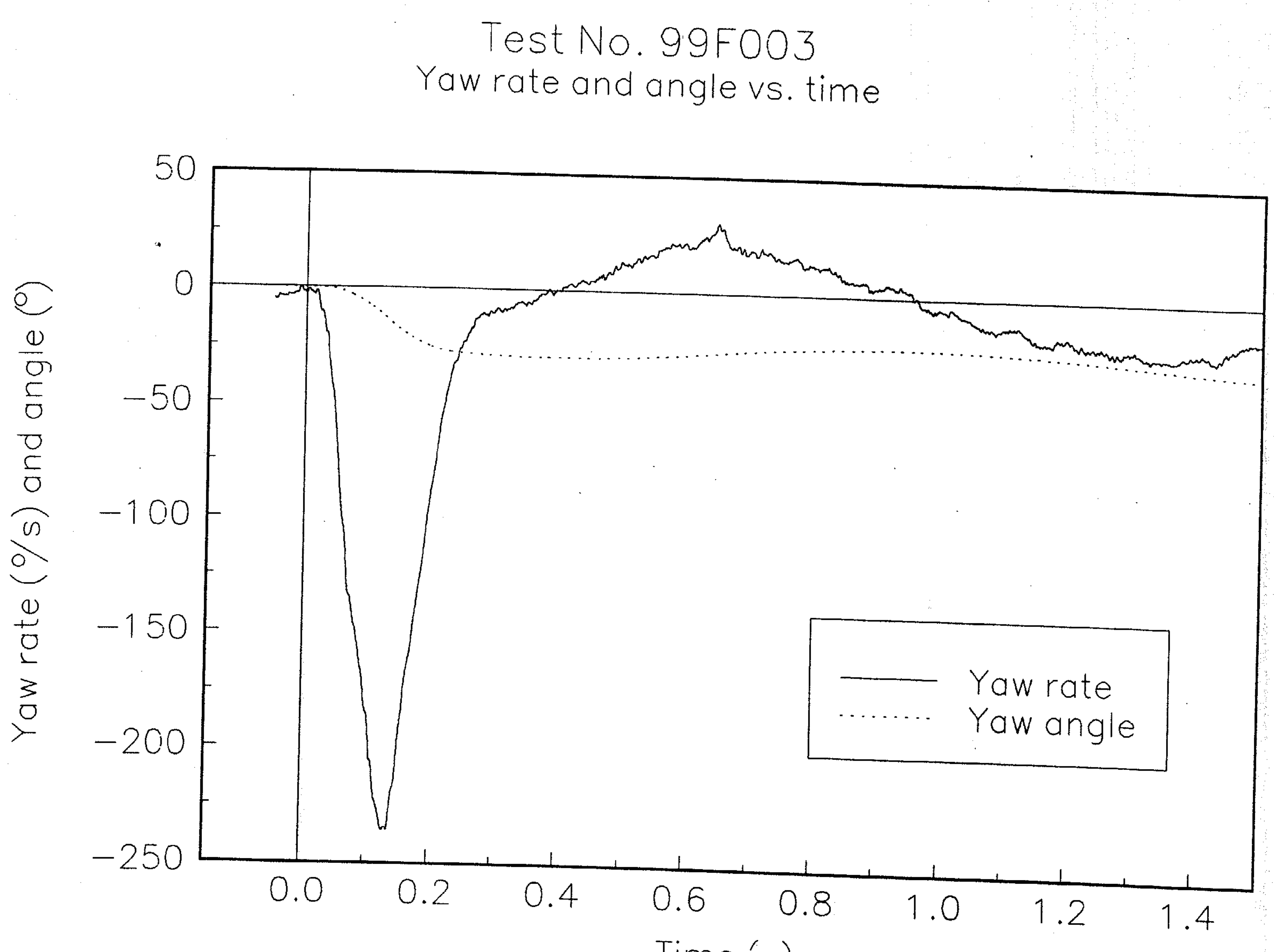


Figure 27. Yaw rate and angle vs. time, test 99F003.

REFERENCES

(1) Ross, H. E. Jr., Sicking, D. L., Zimmer, R. A., and Michie, J.D., *Recommended Procedures for the Safety Performance Evaluation of Highway Features, NCHRP Report 350,* National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 1993.

(2) NHTSA. *Laboratory Procedures for Federal Motor Vehicle Safety Standard 208*, National Highway Traffic Safety Administration, Washington, DC, May 1992.